THE ARCHAEOLOGY OF COASTAL CHANGE, PUERTO RICO

By

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PREFACE

If a world atlas of mythic lands were made, the maps of most countries would depict at least one lake, lagoon, bay, or sea with a sunken city in it. Here you would find the watery trail to Atlantis, Lemuria, Mu (which is not short for Lemuria), Cantref, Tartessos, Llys Helig, Caer Aranrhed, Caer Is, Lyonesse, the sunken islands of Amerindian legends, the *asolagados* or sunken cities of Galicia, and numerous other sites.

Among divers and submariners, legends of sunken cities tend to be regarded with considerable seriousness. This is not at all surprising, for the undersea is our New World. Not unlike conquistadors, divers are explorers who often mistake real wonders for ancient, archetypal fantasies. To divers, the undersea is almost a planet within a planet: a world without gravity, without horizon, without sun, without air. In this liquid realm, the natural and the human-made often blend to perfection.

A sandstone reef may be taken for the wall of a sunken city, particularly in poor visibility. In water over 100 feet deep, the diver's judgement and perception are further impaired by nitrogen narcosis, an euphoria that increases with depth and closely resembles alcoholic intoxication.

At King's Bay, Georgia, aboard a USN nuclear submarine open to civilians for the day, the casual remark of my research led an officer to mention "an incredible archaeological discovery in deep water." He

wouldn't go any further, as the information was supposedly classified "You found a pyramid," I said. Taken aback, the naval officer predictably inquired about my source of information I said I had read about it somewhere To this day, I still wonder what his reaction might have been, had I told him about the power of myths, a power far greater than the nuclear warheads aboard his Grey Lady

This is but one of various instances in which serious, rational mariners and divers have told me of "mysterious ruins" in the sands of the sea Is it all fantasy, as most Spanish archaeologists claim when confronted with the possibility that Tartessos (the Biblical Tarshish?) was an actual city lost to the sea? Or is there, perhaps, a geoarchaeological basis behind the legends? The draining of Galicia's Antela Lagoon revealed no signs of the fabled city that was supposed to be there (Cunqueiro 1983 88) On the other hand, the legendary sunken town in The Philippines Lake Taal was recently proven to be true (Hargrove 1986)

The theory of plate tectonics indicates that sunken continents are a geophysical impossibility This is due to the lightweight composition of continents in relation to the denser ocean floor From a contemporary geological perspective, the idea of a sunken continent à la Mu or Atlantis is as absurd as a sunken iceberg, or a sunken ice cube in your favorite drink. Just as the iceberg floats at sea, the continental masses "float" over the denser rock beneath them (Roberts 1977 24)

Nonetheless, sunken coasts are a fact Sunken islands are a fact Cities in the sea are a fact As for the Deluge, which is found in religious traditions throughout the world, an oceanographer of the stature of Cesare

Emiliani has suggested it may refer to the Holocene marine transgression (Emiliani et al 1975), which flooded the world's coastline after the Wisconsin glacial era. This is a challenging view that many archaeologists would reject in favor of localized floods, combined with diffusion of legends (Ceram 1972: 354).

The problem with Emiliani's hypothesis is not the reality of the Holocene transgression, amply proven by earth scientists, but rather ascribing to myths an event that began some 15,000 years ago and which lasted thousands of years. As a witness to a recent hurricane, I am well aware that local disasters in prehistory may have been terrifying enough to create apocalyptic myths.

Then again in favor of Emiliani's hypothesis, there may well have been a stage in the Holocene transgression fast enough to become a 'cultural event' (Flemming 1972: 27). If this is the case, then the Biblical Deluge is essentially true, which is not to say that only Noah's family survived it. As scientists, we should recognize the great amount of symbolic and historic knowledge that is contained in religious writings regardless of how poetic the presentation.

Perhaps the mystical and scientific views on sunken kingdoms have never come closer than at Bimini Road, an undersea pavement off Bimini Island in the Bahamas. The story goes back to 1940, when psychic healer Edgar Cayce predicted that, sometime between 1968 and 1969, parts of Atlantis would be rediscovered near Bimini. And indeed, in 1968, the now famous "road" was discovered (Berlitz 1974). Other expeditions followed, revealing additional walls and pavements. These undersea discoveries thrilled the Atlantologists, and called the attention

of prestigious cinematographers and undersea explorers such as Dimitri Rebikoff, Jacques Cousteau, and Alan Landsburg (1976) of the In Search Of television series

But exactly what is the nature of the Bimini Complex? To begin with, the famous sunken "road" is beachrock, naturally formed at the intertidal zone during a lower sea level. The "megalithic blocks" of the "road" are impressive, but they suspiciously resemble a tesselated pavement smoothly cut by natural water weathering. At least some of the sunken wells in Bahamian waters appear to be the ruins of historic turtle kraals, and the "eroded temple pillars" look very much like speleothems from submerged karst caves. As for the artifacts supposedly recovered by divers: I have yet to see the photograph of an Atlantean pottery shard, or any prehistoric pottery shard for that matter, found at Bimini Road. To this day there is no conclusive evidence that a prehistoric civilization was destroyed by a seismic cataclysm in the Bahamas. Then again, there is no conclusive evidence against it.

Lest I be taken for an anti-mystic, I should say that my own interest in sunken lands originated as a childhood vision. This fantastic daydream led me to Poe, Byron and Verne, and further intensified my passion for the undersea. Strangely enough, my favorite coral garden was the same reef where I would later discover a sunken prehistoric hamlet (Vega 1981, 1982). As a scientist, it took me years of great intellectual and physical effort, and the retrieval of hundreds of artifacts and ecofacts in the process, before I was able to ascertain that I had found the actual ruins of a sunken prehistoric village--as opposed to the secondary deposition of artifacts eroded from the nearby coast, or a Bermuda Triangle mirage.

My discovery was a far cry from Poe's City in the Sea. Instead of "shrines and palaces and towers," I found pottery sherds, stone adzes, and a small ceramic face. But that rather plain submerged shell midden—the first to be excavated in the Caribbean—showed me a new way of looking at prehistory.

Coastlines are not fixed boundaries. They are landforms in eternal change, drifting back and forth across island and continental shelves. In the final analysis, the myths of sunken lands convey a fundamental truth: what was once dry land may be sea-bed now.

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THE ARCHAEOLOGY OF COASTAL CHANGE, PUERTO RICO

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Archaeological interpretation of tectonic and eustatic land-sea level changes indicates a highly dynamic Holocene environmental history for the Caribbean Archipelago. By 15,000 B.P., sea level may have stood 100-130 m below present mean sea level (MSL). Bathymetric and paleontological data show that the Caribbean offshore islands were not attached to the American mainlands during or after the Wisconsin glacial maxima. A lower sea level facilitated a maritime entry of early preceramic peoples into the Caribbean. It is hypothesized that the first migrants were maritime hunter gatherers who ventured offshore in response to the gradual demise of the continental megafauna. The tectonic component of relative sea level is examined for the main island of Puerto Rico as a case study. Geoarchaeological interpretation of 29 prehistoric and 9 historic littoral sites indicates a NE downward tilt (>5 m) since preceramic times, as deduced from the inland position of preceramic middens on the south coast, and the absence of preceramic sites on the north coast, except for the prograded outlet of the Loiza River. The roughly uniform, estimated shoreline migration (ESM) of ceramic sites on all four coasts suggests that the tectonic tilt waned by 2000

B P Slight marine transgression of Ostionoid ceramic sites and historic military installations suggests a global sea level rise of 1 m or more since 1000 B P Preliminary geoarchaeological research for the Virgin Islands supports the tectonic unity of these islands and Puerto Rico Submerged preceramic sites are predicted for the north coasts of Puerto Rico, Virgin Gorda, Anegada, and possibly the other islands in between In these areas, preceramic middens averaging 25 m in diameter should be found on the inshore vicinity of beachrock pavements, at a water depth of 6 m or more

CHAPTER 1
THEORETICAL FOUNDATIONS

Introduction

> Since things are far more ancient than letters, it is not to be wondered at if in our days no record exists of how these seas covered so many countries and if moreover such record ever existed the wars the conflagrations the deluges of the waters the changes of language and of laws have consumed every vestige of the past.
> Leonardo da Vinci 1452 1519 (1995 27)

> Like the sea itself the shore fascinates us who return to it, the place of our dim ancestral beginnings.
> Rachel Carson (1955. vii)

As early as 235,000 400,000 B P , Lower Paleolithic hominids explored the edge of the sea in search of shellfish at Terra Amata, Nice Southern France (de Lumley 1969; Ville 1983) Fully modern humans appear in the archaeological record by 35,000-40,000 B P , but it is only by c 9000 B P that the first coastal cultures appear (Cohen 1977 121) Today, there is growing recognition that this may well be a biased picture created by the submergence of coastal sites (Flemming 1985; Ruppé 1980a 33) Perhaps there were shellfish eaters at the same time, or before, there were big-game hunters, but their sites are now under water In the last 17,000 years, sea level may have risen an astounding 100-130 meters (330-426 ft), drowning millions of square miles of the world's coastal zones (Kennett 1982 268, Harmon et al 1978 205, Milliman and Emery 1968 1121)

Myths and folklore tell us of towns and kingdoms drowned by the sea. Some of these stories are pure fancy; others are based on actual events, such as the dramatic sinking of the "pirate city" of Port Royal, Jamaica, by an earthquake in 1692 (Hamilton and Woodward 1984).

Since the 1930s, archaeologists speculated that prehistoric men lived on portions of the now submerged continental shelf (Blene 1937). It was assumed, however, that such sites would have been destroyed by the rising seas of the Holocene transgression. Today, the archaeological community is beginning to recognize that the traditional "sand castle hypothesis" is false. In the last two decades, diving researchers have proven that sunken land sites of virtually any age may survive inundation in both fresh and salt water environments, and be systematically studied under water.

Submerged land sites of prehistoric, classical, or historic cultures have already been found in Florida (Cockrell 1980, Ruppe 1980a), California (Masters 1995, Moriarty 1981), Maine (Richardson 1985), Jamaica (Mayes and Mayes 1972), Puerto Rico (Vega 1981, 1982), Nevis and St. Eustatius (Marx 1973), Denmark (Andersen 1980), Russia and Yugoslavia (Rackl 1968), Sweden (Larsson 1983), France (Geddes, et al. 1983, Prigent, et al. 1983), England (Bacon 1986), Spain (Landsburg 1976, Marx 1986), Portugal (Claudio Bonifacio, personal communication 1985), Gibraltar (Waechter 1964), Italy (Lewis 1973), Greece (Gifford 1983, Pirazzoli 1987, Sordinas 1983), Turkey (Flemming, et al. 1973, Carter 1979), Tunisia and Egypt (Martin and Flemming 1977), Libya (Flemming 1971, 1980), Israel (Raban 1983), Lebanon (Frost 1973), Tasmania (Jones 1983), The Philippines (Hargrove 1986), etc.

Research Goals

We cannot discover new oceans unless we have the courage to lose sight of the shore
André Gide (in Hauser 1987: 147)

The brown Indians and the gardens of the sea, and the beer and the work they were all one thing and we were that one thing too
John Steinbeck (1959: 272)

The original idea behind this study was to search for submerged and intertidal archaeological sites in Puerto Rico. Departing from the author's previous discovery and excavation of a submerged prehistoric site off Puerto Rico's north shore (Vega 1981), it came as a natural progression to search for other sites, to demonstrate that the immersion of Caribbean archaeological sites is the rule, not the exception.

As other submerged and intertidal sites were found and analyzed, a formal theory of Caribbean coastal changes began to take shape. Reexamination of the literature formally revealed what the author had previously suspected from observation: that Caribbean archaeology has wrongly presented the coastal environment as a passive actor, as an unchanging landscape that yields shellfish *ad infinitum*.

Studies of Caribbean prehistoric migrations are characterized by only cursory reference, if any, to Holocene sea levels (Dávila 1985, Cruxent and Rouse 1969, Fine 1971, Raggi 1973, Rouse, 1964, 1986, Rouse and Allaire 1978). Among the few exceptions are the pioneer papers by Nicholson (1976a, 1976c), and Ruppé (1980b), discussed elsewhere.

Beyond sea level per se, the region has produced few studies linking archaeology to oceanography, clearly validating Watters (1983) criticism that Caribbean archaeology is characterized by a significant terrestrial bias

While changes in land ecology are deemed central to prehistory, changes in marine ecology remain largely unexplored.

Extensive personal observations confirm that most native Caribbean archaeologists are not particularly attracted to or knowledgeable of the sea (Watters 1983 532), an ironic situation worthy of sociological inquiry The irony is not simply that we are islanders, but more importantly, that the prehistoric peoples whose lifeways we are trying to reconstruct lived in close physical and spiritual bond with the sea

With these problems in mind, three research objectives were envisioned, to develop a maritime perspective on Caribbean prehistoric migrations (Chapter 3), to search for intertidal and submerged sites in Puerto Rico as a case study (Chapter 4), and to integrate the field data into a regional model of Caribbean coastal geoarchaeology (Chapter 5)

Definition of the Problem

> It is said that within a few years Sable Island has been reduced from forty miles in length to twenty and that of three lighthouses built on it since 1880 two have been washed away and the third will soon be engulfed
> Capt. Joshua Slocum, 1900 (1956 24)

> I have heard it said that some people do not believe in the existence of cities in the sea. What a pity not to believe in facts which are as strange as any legend.
> Nicholas C Flemming (1972, xvii)

Submerged land sites present a number of unique problems to the researcher Where do you dive for them? What environmental and site modifications occurred as a result of immersion? Are the artifacts on the sea floor an actual site, or the results of secondary deposition due to site erosion on the nearby coast? How do you go about surveying and excavating such sites? How do submerged land sites help us recreate coastal change?

Locating Submerged Land Sites

The first submerged land sites to be studied were Mediterranean classical and pre-classical ports In the nineteenth century, engineer Giuseppe de Fazio hired sponge divers to survey the sunken harbors of Pozzuoli and Miseno, in the Bay of Naples In 1901, archaeologist Robert Gunther continued de Fazio's survey through a glass-bottom box (Rackl 1968 184) In 1910, employing hard-hat divers and free swimmers, Gaston Jondet discovered the sunken remains of the once spectacular harbor of Pharos near Alexandria, Egypt (Flemming 1972 40)

That the Mediterranean is the cradle of submerged land archaeology is not at all surprising Fortified villages date back to 6,000 B P , and the coast is crowded with ruins ranging from Neolithic towns to the Roman Empire Classical ports alone run in the hundreds, many of which have been submerged by tectonic movements in a highly active seismic region (Flemming 1972 184) Numerous sunken sites are visible from shore, and particularly from the air In 1934, in a reconnaissance flight along the Lebanese coast Jesuit priest and archaeologist Antoine Poidebard discovered the sunken ruins of the Phoenician city of Tyre, which he promptly surveyed with sponge divers (Rackl 1968 175)

Following the invention of the Cousteau-Gagnan aqualung in 1943, scuba diving became a popular Mediterranean sport after the end of World War II This led to the discovery and exploration of numerous sunken ports By the early 1970s, divers and archaeologists had located over one hundred "cities in the sea" (Martin and Flemming 1977 223)

The end of World War II also saw the rise of deep-sea oceanography, producing a quantum leap in sea level studies (Emiliani 1972) Combined

with the availability of lightweight scuba gear, and the discoveries of Mediterranean submerged land sites, the new oceanographic discoveries presented a challenge to prehistoric archaeologists.

Searching for drowned prehistoric sites was first proposed in the United States by Goggin (1960), with early discussions by Solecki (1961), Shepard (1964), Emery and Edwards (1966), Salwen (1967), Bullen (1969) and Warren (1964). At the time, the archaeological community was not ready for diving and sea level research, and the problem remained more theoretical than practical.

In the Caribbean, the search for prehistoric sunken sites was first proposed by Nicholson (1976a), following a survey of Antigua, which indicated that shell middens on the NE coast are undergoing marine transgression, while middens on the SW coast are now inland. More recently, Ruppé (1980b) has also encouraged a search for drowned Caribbean sites, based on his own successful underwater research in West Florida (Lightfoot and Ruppé 1980, Ruppé 1980a).

Environmental Variables

Submerged land sites may occur in a wide variety of environmental settings, including sinkholes (Clausen et al.,1979), lakes (Hargrave 1986; Ruoff 1972), rivers (Palmer et al. 1981), submerged karst caves (Flemming 1983: 152), sea caves (Weschter 1964), rias (Larsson 1983), estuaries (Prigent et al. 1983), semi-protected tropical coasts (Vega 1981), sheltered alluvial coasts (Gifford 1983), and high energy coasts (Masters 1983, Muche 1978).

Considering these widely divergent environments, one can only agree with Flemming (1983a: 164) that "no single factor in the geomorphology of the coastal zone is necessary or sufficient to ensure preservation of archaeological remains under water."

Three important variables must be considered here: 1) that the modern coastal environment need not be the same as when the site was immersed, possibly being exposed now but protected then; 2) that the speed of the marine transgression may be a crucial factor in some instances, with fast flooding increasing the chance of site preservation, and 3) that previous subaerial deposition may act as a shield during transgression, even in high energy coasts.

In a comparative analysis of the preservation of sunken sites world-wide, Flemming (1983a: 164) has concluded that most coastal archaeological sites were originally located in sheltered places favored by the original inhabitants, and that most of these sites may survive at least one marine transgression. Undoubtedly, some of the artifacts occasionally found by scuba divers are the result of secondary deposition by longshore and rip currents (Masters 1983: 209). In some cases, artifacts may have fallen from watercraft, or be a part of the scatter pattern of a shipwreck site. Nonetheless, there is ample, world-wide evidence that many land sites do survive the process of immersion with little or no damage at all. In the long run, the sea may actually be a preservational agent, providing anaerobic conditions in some instances, and protecting the site from the anthropogenic disturbances so characteristic of many land sites: plowing, construction, sand extraction, and looting.

Method and Theory

Underwater surveying and excavation techniques are discussed in detail by Bass (1970), Nieto (1984), Peterson (1973), and St. John Wilkes (1975). At the nuts-and-bolts level, excavating a sunken land site is somewhat akin to shipwreck archaeology. There are, of course, fundamental differences in the nature of both sites. In principle, shipwrecks are not stratigraphic sites. On occasion, however, two or more shipwreck sites may be superimposed, or be found within the larger stratigraphic context of a harbor.

For a general overview of shipwreck archaeology, see Bass (1972, 1988), Johnstone (1974) and Throckmorton (1987). Theoretical issues of shipwreck archaeology are discussed by Blackwater (1981), Gluckman (1981), Gould (1983), Muckelroy (1978) and Murphy (1981). For a general history of underwater archaeology, including both shipwrecks and sunken land sites, see Hoffmann (1987), Muckelroy (1980), and Rackl (1968).

In the most elaborate theoretical discussion of shipwreck sites to date, Muckelroy (1978: 160) argues against the traditional "good-bad" shipwreck dichotomy, indicating that most wreck sites are neither totally coherent nor totally scattered. This same principle is applicable to the stratigraphy of submerged land sites, which may range from intact to completely disturbed. As mentioned elsewhere, the fundamental point is that submerged land sites are not necessarily without stratigraphy (Andersen 1980, Cockrell 1980, Flemming 1983a).

At Isla Verde, a submerged prehistoric site off Puerto Rico, the author had no difficulty excavating perfectly vertical pits in mud, using a home-made water dredge (Vega 1981). However, it is an altogether different

story in sand or silt, both of which have a stability angle generally under 45 degrees As one solution to this problem, Lewis (1973 247) has used a vertical caisson, large enough to accommodate a diver with a water dredge or air-lift for controlled excavation Another solution has been offered by Gifford (1983), consisting of a diver-held corer Both techniques have proven quite useful to these diving researchers, but neither has been tested on densely-packed, underwater shell middens.

Paleoshorelines

One of the fundamental postulates of this dissertation is that archaeological sites may be used as markers of coastal change This is by no means a new idea, pioneered for Puerto Rico by Kaye (1959) More recently, Fairbridge (1976) has traced Holocene sea levels in Brazil by radiocarbon dating of shell middens in ancient beach ridges From an environmental perspective, the study of coastal archaeological sites is relevant to geomorphologists, geographers, and indirectly, to engineers and planners engaged in coastal erosion and sedimentation control (Barth and Titus 1984, Brooks et al 1979, Chardon 1977) As advocated by the Commission on the Coastal Environment, understanding coastal change requires "historical sources as well as geomorphological methods" (Bird 1985 x)

Reconstructing shoreline migration on the basis of archaeological data is an archaeological endeavor, whether it is conducted by an archaeologist, geomorphologist, or geographer It takes archaeological thinking and technique to define the relationship of a structure or feature to the ancient shoreline Mistaking a breakwater for a quay or house wall would produce a completely erroneous evaluation of shoreline migration for

that particular coastline Indeed, many of the purported sites of Atlantis are nothing more than the erroneous interpretation of sea walls as the remains of sunken houses and temples

Research Domains

No rays from the holy heaven come down
On the long night time of that town
But light from out the lurid sea
Streams up the turrets silently
Edgar Allan Poe 1809-1849

Nunca sabremos quién tocaba las campanas
en la catedral sumergida de Debussy
Alvaro Cunqueiro (1983 88)

Evidence of sea level and shoreline migration may be profitably grouped into three research domains 1) geomorphological, 2) cultural, and 3) historical These domains comprise particular sources of evidence and time frames, each encompassing a shorter but more finely dated sequence of time

For purposes of this project, the geomorphological domain comprises the Holocene period, roughly 15,000 B P to the present Potential geomorphological indicators of coastal change in the Caribbean include beachrock, eolianite, shallow water mollusks, coral, rock algae, oolite and oolite rock, salt marsh peat, drowned river banks, speleothems, fossil beach ridges, sea caves, drowned forests, tidal terraces, and sea level nips

The cultural domain comprises the range of human occupation of the study area, possibly extending back to 7,000 B P for the Caribbean (Alegria et al 1955, Dávila 1985 Meggers and Evans 1979 543, Pine 1971 Rouse and Allaire 1978 465, Veloz and Ortega 1978, Willey 1976) Cultural

indicators of coastal change include preceramic and ceramic shell middens, human burials, petroglyphs, pictographs, and isolated artifacts embedded in beachrock.

The historic domain ranges from the foundation of the first European settlements to the present. For the Caribbean, this period begins in the last decade of the 15th century, with the settlements of Navidad, Isabela, Concepción de la Vega and Santo Domingo in Hispaniola (Hoffman 1980, McAlister 1984, Parry 1963, Sauer 1966). For Puerto Rico, the historic period begins in 1506, with the foundation of Higuey on the west coast of the island, by Juan Ponce de León, followed in 1508-9 by the settlements of Caparra and Guánica, on the north and south coasts respectively (Tió 1956-54).

Historic markers of coastal change include port installations, coastal fortifications and habitation sites, historic and modern maps, literary descriptions, railroad tracks, aerial photographs dating back to the 1930s, historic artifacts embedded in beachrock, and modern coastal structures in general.

CHAPTER 2
CHANGING LEVELS OF LAND AND SEA

Marine transgressions may occur due to a variety of local, regional, or global processes. Land may be eroded or subside due to tectonic movement, postglacial rebound, isostatic depression, and sediment compaction (Evans 1971, Morner 1971, 1980, Morrison 1980). Sea level may rise due to changes in the volume of ocean water or of ocean ridges (Donovan and Jones 1979; Clark et al. 1978, Coleman and Smith 1964; Curray 1961, Emiliani et al 1975). Following current theory, the major agent of coastal change has been a global or eustatic sea level rise due to the melting of land-blocked ice, possibly resulting from variations in the earth's orbit (Hays et al. 1976: 1121).

Sea level remains a controversial topic of vast complexity. An impressive body of literature has been accumulated (Richards and Fairbridge 1965), but there is serious disagreement on the chronology and boundaries of Quaternary sea levels. When did the sea reach its present level? Did it rise smoothly, or in an erratic fashion? Did it rise above present mean sea level during the Holocene transgression? These questions need to be addressed at the regional level, as global sea level curves are not sensitive enough to account for local and regional variations (Blackwelder et al. 1979, Chappell 1974, Chappell and Thom 1977, Cooke 1978, Fairbridge 1976, Harmon et al. 1978).

Glacial and Tectonic Eustasy

In the six hundredth year of Noah's life, on the seventeenth day of the second month—on that day all the springs of the great deep burst forth, and the floodgates of the heavens were opened. And rain fell on the earth forty days and forty nights.
The Bible. Genesis 6:11

The gods feared the flood, they fled. They climbed into the heaven of Anu. The gods crouched like a dog on the wall. For six days and nights wind and flood marched on. the hurricane subdued the land. And all mankind was turned into mud.
Epic of Gilgamesh (In Ceram 1972:314)

Eustatic movements of sea level are produced by changes in the volume of ocean water, or changes in the volume of ocean basins. In theory numerous factors may alter the volume of the oceans, including the production of juvenile water and its reabsorption in the earth's mantle, changes in the moisture content of the atmosphere, desiccation of ocean basins, changes in mean oceanic temperature, and changes in the volume of land-locked ice (glacio-eustasy). There is a general consensus that glacio-eustasy is by far the most significant of these processes, the other factors having minor or no impact on Quaternary sea levels, as far as the problem is presently understood (Donovan and Jones 1979: 187).

In the case of mean water temperature, a rise of 1°C would increase sea level by a mere 60 cm (West 1979: 163). Deep-sea coring indicates that six million years ago, the Mediterranean became isolated from the rest of the ocean, dried up, and turned into a desert (Hsu 1972: 27). This may have resulted in a significant rise in sea level of some 12 m (39 ft.). However, there is no evidence that a desication of that magnitude occurred during the Quaternary Period.

During the last two million years, the earth has undergone some twenty ice ages, in cycles of roughly 100,000 years (Flemming, 1985: 19). These glaciations are caused by a fall in atmospheric temperature, resulting

in increased snowfall, reduced ablation (glacial erosion), and increased freezing of ground water (West 1978: 155). With each glaciation, water is abstracted from the ocean, resulting in a drop in sea level (Figure 1). The process does not include the formation of icebergs and ice shelves, as these floating bodies of ice displace their own mass of water.

The cycles of cold (glacial) and warm (interglacial) periods is one of the fundamental mysteries of the earth. Proposed explanations include variations in the output of the sun, partial blockage of solar energy by interstellar or volcanic dust, changes in the deep circulation of the oceans, continental drift from circum-polar to tropical regions, etc. Current theory suggests that these climatic variations are caused by changes in the earth's orbital geometry, which occur in dominant cycles of 100,000 years (Hays et al. 1976: 1121).

Significant eustatic fluctuations in sea level may also be caused by changes in the volume of ocean basins. The primary factor of basin volume is the growth of mid-ocean ridges, which form an undersea mountain chain that runs for more than 60,000 kilometers (37,000 miles), and rise an average of 3,000 m (9,800 ft.) above the abyssal plain (Roberts 1977). Vertical movements of ocean ridges may result from sea-floor spreading, producing a gradual sea level rise of 1 cm (.39 in.) per 1,000 years (Donovan and Jones 1979: 189).

In principle, the capacity of ocean basins may also be reduced by the deposition of land-derived sediment. The Mississippi River alone discharges over 500 million metric tons of sediment per year (Evans 1973: 89). However, much of this effect is cancelled out by isostatic depression of crust beneath the added load, which may cause localized submergence of

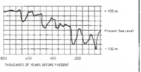


Figure 1 Glacio eustatic sea level change for the past 800,000 years (after Morelock 1978 4, Fig 5)

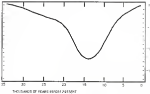


Figure 2 Sea level curve for the U.S Atlantic Continental Shelf for the last 35,000 years (after Milliman and Emery 1968 1122, Fig 1)

coastal areas through downwarping, as discussed in the following section. Finally, changes in the shape of the earth may introduce considerable regional differentiation into the eustatic sea level curve (Kennett 1982: 266). This geoidal factor is controlled by the earth's rotation and mass distribution, and in theory, may cause a rise in sea level in some regions and a drop in others (Donovan and Jones 1979: 190, Morner 1980).

Regional and Local Processes

> Atlantis was an island larger than Libya and Asia put together. though it was subsequently overwhelmed by earthquakes and is the source of the impenetrable mud which prevents the free passage of those who sail out of the straits into the open sea.
>
> Plato c.427-347 B.C. (1971: 129)

> The myths of the Dakota Sioux, Manbans, Delaware and Iroquois refer to an island in the Atlantic Ocean "towards the sunrise" which sank. The Mandans say that a tribe of white men lived there.
>
> Jeffrey Goodman (1982:20)

Marine transgressions may occur at specific seacoasts due to land movements independent of eustatic sea level. Blocks of land may subside along geological faults due to slight tectonic changes. Movement may be gradual or occur in a seismic seemingly apocalyptic landslide, such as the catastrophic destruction of Halike in Greece (Morrison 1980: 134), or Jamestown in the Caribbean Island of Nevis (Marx 1972: 139). Robson (1964) has compiled a listing of eastern Caribbean earthquakes since 1530. Catastrophic landslides may also be caused by volcanic eruptions, as the earth's crust readjusts to the rapid outpour of lava (Martin and Flemming 1977: 224, Boillet 1984: 23).

Land movements may also result from the loading or unloading of ice, sediment, or water. Parts of Scotland, Scandinavia, and Canada, once glacial, are currently being uplifted as a response to ice unloading with a

corresponding downward movement in other areas (West 1977 151) Deltaic areas may be gradually submerged by isostatic depression under the heavy load of river sediments (Coleman and Smith 1964) This process may be further compounded by sediment compaction (Flemming 1977 359)

Storm surges are capable of producing localized marine transgressions of devastating power In 1900, at Galveston, Texas a hurricane surge caused the sea to rise 4 5 m (15 ft) above its normal tidal range, on top of which giant waves invaded the city (Bascom 1964 78) Millás (1968) and Salivia (1972) have compiled chronological listings of Caribbean storms and hurricanes since 1432

Significant coastal modification may result from erosion, with or without changes in the relative height of land and sea. Holderness, Dunwich, Winchelsea and numerous other English settlements are now under water due to erosion (Morrison 1980 132) A similar fate happened to Tyndaris, on the north coast of Sicily (Flemming 1972 194) Anthropogenic factors may accelerate the process of sediment loss The construction of breakwaters, quays, etc , the extraction of beach sand, and the clearing of the coastal flora may all result in massive, localized erosion (Chardon 1977) Contrary to the opinion of many archaeologists and geomorphologists, eroded sites may survive the process of immersion In Dunwich, England, divers working in zero visibility have excavated parts of a medieval church off an eroded coast (Bacon 1986 21)

Late Quaternary Sea Level History

Deluge The great flood that appears in the religious traditions of virtually all peoples and that destroyed all but a few inhabitants of the earth.
Charles Winick (1975 162)

In ancient times when balance was lost on the planet a great flood came to destroy all that which was on the earth so that the world could be reborn
Matsuwa, Huichol Shaman (In Halifax 1979:250)

Sea level curves have been produced by Blackwelder et al (1979), Bloom (1967), Clark et al (1978), Curray (1961), Fairbridge (1961), Kidson (1982), Milliman and Emery (1968), Morner (1971), Scholl and Stuiver (1967), Shepard (1963), and others On the basis of the tectonic, geoidal, and isostatic variables discussed above, it is clear that an exact, global sea level curve is impossible. Thus, the concept of eustasy should be understood as an average sea level (Walcott 1971 10) For the archaeologist, the problem implies difficulty in matching sea level curves with cultural chronologies (Ruppé 1980a 42) In other words, it is impossible to have a strict global correlation between depth of submerged land sites and their ages (Table 1) There is general consensus that the sea was near its present level by about 35,000 B.P (Figure 2). Then it began to drop as the Laurentide and other Pleistocene ice sheets expanded over the Northern Hemisphere (Emiliani et al 1975 1083) By 20,000 to 15,000 B P , sea level reached its lowest point in the Wisconsin glaciation. Estimates for this lowest sea level stand include minus 60 m (Blackwelder et al 1978), minus 85-90 m (Morner 1971), and minus 130 m (Milliman and Emery 1968) By 17,000-15,000 B.P., the Holocene transgression began, with a rapid rise in sea level in the order of 8 mm (.31 in) per year, until about 7,000 B P (Kennett, 1982 270) By that time, sea level may have been some 10 m (32 ft.) below present level (Shepard 1963).

From 7,000 B P onwards, the sea continued to rise at a much slower pace At this point, there are important disagreements among researchers

TABLE 1

Global Correlation of Prehistoric Submerged Land Sites

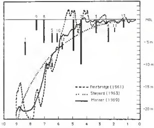
	Site Location	Depth (Meters)	Cultural Affiliation	Years B P
1	Strait of Öresund Denmark and Sweden	5-8	Mesolithic	9000-8000
2	Normandy A NW France	8 7	Neolithic	8600-4000
3	Normandy B NW France	0-3	Bronze Age	4000-3000
4	Normandy C NW France	2-5	Iron Age (Salt Works)	3000-2000
5	Leucate South of France	3-5	Neolithic	7000-6000
6	Kelladha Bay Argive, Greece	10	Neolithic	7000-5000
7	Kyra Panagia Sporadhes Greece	0 10	Neolithic to Bronze Age	7800-3000
8	Israel A Mediterranean Coast	0-5	Neolithic to Chalcolithic	8000-5000
9	Israel B Mediterranean Coast	0-2	Neolithic	8000-7000
10	Southern California U S.A.	2-8	La Jollan (Preceramic)	8000-5000
11	West Florida A U S A.		Perico Island (Ceramic)	2000
12	West Florida B U S.A.	5 0	Middle Archaic (Preceramic)	8000
13	North Coast, Puerto Rico Caribbean	0-2	Ostionoid (Ceramic)	1200-800

(Source Masters and Flemming 1983 607, Ruppé 1980a, Vega 1981)

(Figure 3) Van Andel and Laborel (1964), Fairbridge (1961), and others have proposed sea level oscillations with higher-than-present sea levels in the late Holocene, while Curray (1961), Schell and Stuiver (1969), Shepard (1963) and others have reported evidence of a smooth sea level rise approaching the present level by 4,000 to 2,000 B.P. Indirect corroboration from oxygen isotopic analyses of glacial history support slightly higher late Holocene sea levels than at present (Kennett 1982: 273), but the problem very much remains an open question.

The rising seas were marked by interruptions or stillstands. These periods of stationary sea level allowed the development of marine terraces, which may be observed under water. Prominent submarine terraces are found in the Caribbean, the Gulf of Mexico, and the Pacific at an average depth of 15 m (49 ft.) and 40-50 m (130-165 ft.). Of course, the depths of marine terraces may be affected by local tectonism, so that Pleistocene terraces may be found in shallow water and even above present sea level (Emery 1981).

Stillstands also allowed the formation of sea caves, beaches, and associated geomorphological features. The archaeological importance of stillstands cannot be overestimated, for these periods of stationary sea level made possible the formation of permanent or semi-permanent, stratified coastal sites, as discussed in Chapter 3.



Black bars represent the depth range and median age of submerged prehistoric sites, as outlined in Table 1

Figure 3 A comparison of three eustatic sea level curves, for the last 10,000 years (after Fairbridge 1974 232, Fig 1)

CHAPTER 3
CARIBBEAN PREHISTORIC MIGRATIONS

The Sea and the Islands

They came because they were afraid or unafraid because they were happy or unhappy because they felt like Pilgrims or did not feel like Pilgrims. There was a reason for each man they were coming to find something or leave something or get something to dig up something or bury something or leave something alone.
Ray Bradbury (1967 72)

I must remember to see with island eyes.
Anne Morrow Lindbergh (1975 120)

The Caribbean Sea is separated from the Atlantic Ocean by a chain of islands known as the West Indies Political and historic divisions aside, the Caribbean Archipelago is hereby divided into five groups 1) Bahamas-Turks-Caicos Islands, including Mouchoir, Silver, and Navidad Banks, 2) Greater Antilles–Virgin Islands, extending east to Anegada Passage, 3) the Lesser Antilles, from Sombrero to Grenada, and including the Dutch islands of Aruba, Curaçao, and Bonaire, 4) the Continental Islands, including Trinidad, Tobago, and the Margarita Island group, and 5) the Grand Cayman Banco Gorda group, including Misteriosa and Rosario Bank.

Structurally, most of the region lies atop the Caribbean lithospheric plate, which interacts with the Cocos plate to the east, and the much larger North American and South American plates (Figure 4) For a general discussion of plate tectonics, see Baillet (1984), and Roberts (1977) The

evolution and movement of the Caribbean plate are discussed by Malfait and Dinkelman (1972), Sykes et al (1982), and Perfeit et al (1980)

The northeastern boundary between the Caribbean and North American plate is marked by the Puerto Rico Trench Ninety five miles NE of Puerto Rico, the Trench reaches a depth of 9, 219 m (30 245 ft), the deepest zone of the Atlantic Ocean To give an idea of its depth, the Puerto Rico Trench has enough vertical space to accommodate the 8,840 m (29,000 ft) of Mt. Everest (Suárez Caabro 1979 5) This is a seismic zone, characterized by a large concentration of earthquakes but no volcanic activity since the Oligocene (Perfeit et al 1980 128) In contrast, the southern portion of the island arc has exhibited volcanic activity as recently as 1977, at St Vincent's Soufrière (Deane 1985 193)

Estimates of relative movement between the Caribbean and North American plates provide a maximum value of 0 5 cm/yr (Malfeit and Dinkelman 1972 265) Caribbean fossil records indicate an absence of large, continental paleofauna the one exception being the sloth (Alvarez 1951, Morbán 1984, Velez and Ortega 1976 160), discussed later The absence of other large Pleistocene mammals indicates that the main channels and passages of the Caribbean Sea remained open during the Quaternary and earlier

Applying Milliman and Emery's (1968) Atlantic sea level curve to the bathymetry of the Caribbean, it is possible to reconstruct the major outlines of the Circum-Caribbean region during the Holocene Figure 5 presents a hypothetical reconstruction of the Caribbean by 17,000 B P , at the end of the Wisconsin regression, with sea level 100 130 m (328-426 ft) lower than at present By this time, Paleo Indians may have been present in Central America The record is rather poor, but there is evidence of fluted

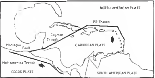


Figure 4 Tectonic setting of the Circum Caribbean Region (after Malfait and Dinkelman 1972 257, Fig 5)

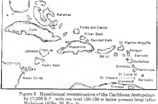


Figure 5 Hypothetical reconstruction of the Caribbean Archipelago by 17,000 B P , with sea level 100-130 m below present level (after Nicholson 1976a 22, Fig 2)

points from big game hunters in Costa Rica and Guatemala (Lynch 1978 460) More importantly, it is assumed that Central America acted as a land bridge for Paleo-Indians migrating from North to South America Unless we accept the radical theories of Antarctic or trans-oceanic migrations (Jett 1978), it is clear that the human presence in Central America is older than the earliest South American Paleo-Indians, possibly dating back to 17,000 20,000 B.P (MacNeish 1971)

According to Rouse and Allaire (1978 465), people started migrating into the West Indies possibly as early as 7,000 B P This entry date is supported by Pina (1971), Veloz and Ortega (1976 149), Willey (1976 1), and others Raggi (1973) suggests a possible entry between 15,000 and 6,000 B P , while Nicholson (1976a) suggests possible migrations as early as 17,000 B P

Regardless of the time of entry, it is clear that the first migrants used some type of watercraft to cross the passages from the mainland(s), and then from island to island Prehistoric seafaring is discussed in detail later The important point here is that the first West Indians did not walk into any of the offshore islands They were navigators in a semi-enclosed sea

A lower sea level implies higher elevation of mountains and sea cliffs, ergo improved vision of distant islands Standing on a beach or boat, a man with 20/20 eyesight will not see a low-lying island 16 km (10 miles) away, for the curvature of the earth will hide it beneath the horizon of our hypothetical observer If sea level were to drop sufficiently for that island to rise 24 m (80 ft) above sea level, then it would be visible from our hypothetical boat, 16 km away

Paleobotanical and sedimentological studies indicate that much of northeastern South America was arid to semi-arid in glacial times, due to world wide climatic compression (Lynch 1978 465) In Central America and the Caribbean, the climate was cooler and drier, possibly resembling a Mediterranean climate (Nicholson 1976a 20)

Radiocarbon, oxygen isotopic, and micropaleontological analysis of deep-sea cores indicate that, by 11,600 B P , the Caribbean Sea was 3°C cooler than at present (Emiliani et al 1975 1086) These cooler waters may have resulted from lower atmospheric temperatures in general, and from the discharge of glacial meltwater into the Gulf of Mexico via the Mississippi River (Lynch 1978 465)

As the sea level fell, the hydrology of the Caribbean islands was modified towards equilibrium Rivers cut into the "new" coastal plains of exposed insular shelves, followed by downcutting of flood plains Overall, river discharge was probably reduced, while swamps and marshes shrank due to the drier climate and to stream entrenchment (Inman 1983 18)

Cultural Taxonomy

> Let us agree to disagree " said the Martian "What does it matter who is Past or Future if we are both alive for what follows will follow tomorrow or in ten thousand years How do you know that those temples are not the temples of your own civilization one hundred centuries from now tumbled and broken?"
>
> Ray Bradbury (1967 88)

> We could have told our people the usual thing about the advancement of science, and again we would not have been questioned further But the Indian might ask, "Is it advancing, and toward what? Or is it merely becoming complicated?"
>
> John Steinbeck (1976 211)

The Caribbean preceramic implies diverse cultural groups and ecological niches spanning thousands of years (Figures 6 and 7) The first

inhabitants of the archipelago were preceramic seafarers, arriving on the islands perhaps by 7,000 B P (Rouse and Allaire 1978 465) But there were also preceramic (Archaic) cultures that survived into the so-called "Ceramic Age" of Arawak-Carib peoples. Indeed, some preceramic groups survived into the early historic period, as reported by Spanish geographers Andrés Morales and Alonso de Santa Cruz (In Sauer 1969 48)

Much Caribbean archaeological research has been concerned with chronology and taxonomy, at the expense of environmental reconstruction and sociocultural analysis Vacuous confrontations between "schools" are common, generally resulting from the confusion of theoretical constructions with actual events in prehistory Eventually, all cultural theories and taxonomies must be revised, refined or replaced. Islands with known preceramic sites include Cuba (Tabio y Rey 1966), Hispaniola (Moore 1982, Rouse 1982, Veloz and Ortega 1976), Puerto Rico (Alegria et al 1955, Pantel 1976, Ortiz 1976), Vieques (Figueredo 1976, Tronolone et al 1984b), St Thomas (Gross 1976, Tilden 1976), Antigua (Nicholson 1976b), St Kitts (Rouse and Allaire 1978 459) and Trinidad (Harris 1976) Few of these sites are much older than 3,000 B P If the hypotheses presented in this dissertation are correct, most early Caribbean preceramic sites are to be found beneath the sea.

Formal preceramic typologies have been produced by Kozlowski (1974), Pina et al. (1976), Rouse (1951), and Rouse and Allaire (1978) Most researchers would agree that there are three primary typological patterns, as summarized by Veloz and Ortega (1976 165) Pattern 1 is characterized by ground stone artifacts, including stone balls, mortars and conical "manos" Pattern 2 is characterized by stone artifacts produced by percussion flaking, including choppers, scrapers flint knives, and lanceolate

Figure 6 Preceramic cultures of the Caribbean, excluding Trinidad (after Alegría et al 1955, Cruxent and Rouse 1969, Meggers and Evans 1978, Pina 1971, Rouse and Allaire 1978)

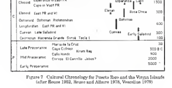


Figure 7 Cultural Chronology for Puerto Rico and the Virgin Islands (after Rouse 1952, Rouse and Allaire 1978, Vescelius 1979)

projectile points Shell artifacts are absent, but some ground stone technology may be present Finally, Pattern 3 is characterized by shell artifacts, including shell picks, conch vessels, and shell gouges

Watercraft and Navigation

> After the dryness of the mountain it was good to come back to the sea again One who was born by the ocean or has associated with it cannot ever be quite content away from it for very long
>
> John Steinbeck (1976 169)

> Time writes no wrinkle on thyne azure brow
> Such as creation's dawn beheld thou rollest now
> George Gordon, Lord Byron (1966 76)

The seafaring heritage of Caribbean aborigines is dead As Thomas (1985 58) indicates for the aboriginal navigators of Oceania the loss is "more than just a set of navigational techniques it is the loss of a way of a life and a conception of the world "

Perhaps, seven or eight thousand years ago, a South American hunter and his family accidentally drifted on a raft down the Orinoco River and into the Caribbean Sea- but they do not concern us here The preceramic peopling of the Caribbean was a complex process involving countless social units and specialized cultural adaptations Whatever the conditions of those first migrations were, they certainly cannot be reduced to a castaway Caribbean Family Robinson To do so is to reduce a complex sociocultural process to a mere historic accident.

The primary aboriginal method of water transport was the canoe, with possible secondary use of rafts The antiquity of canoe making is well established. In Florida, prehistoric dugout canoes dating back to 3,000 B P have been found in wet sites (Bullen and Brooks 1967).

A raft without sails is a very poor craft for ocean navigation, and apparently sails were introduced to the islands in historic times In 1606 a Friar Blasius, originally from Seville, was rescued in Dominica by a British vessel The castaway friar narrated that he had been captured by Caribs, who eventually killed his companions, but spared him for teaching them how to rig sails to their canoes (McKusick 1970 5)

In the Bahamas, Columbus saw canoes "all of one piece hollowed like a tray from the trunk of one tree so large as to contain forty or forty five men while others were so small as to hold one person" (McKusick 1970 5) At Jamaica, Columbus measured one finely decorated canoe at 29m (96 ft) long and 1 8m (6 ft) wide (Sauer 1969 82) This was surpassed by another canoe at Honduras Bay Islands, "as great as a galley, eight feet wide, all of a single trunk" (Sauer 1969 128) Coppler (in Cárdenas 1981 143) describes a Lesser Antillean canoe 27m (90 ft) long which he estimated could carry 85 persons plus cargo Columbus reports that the largest canoes travel with great speed (Colón 1984 32), but neither he nor any other early European explorer mentions the use of sails

Mahogany (*Swietenia mahogani*), cedar (*Cedrela odorata* Gomier), silk cotton (*Ceiba pentranda*) and other woods were used to produce aboriginal canoes (Nicholson 1976c: 101) First, a large tree was killed with fire and left standing to season, then it was felled and hollowed out with controlled firing, and the use of stone and shell picks, celts, and gauges Smoothed out and polished, the log would then be soaked in water Afterwards, the log would be inverted over a bonfire and heated This would increase the wood's elasticity, so that the sides could be forced apart in order to give more beam to the dugout Thwarts or rowers' seats would then be inserted, keeping the sides apart

In the case of large canoes, the ends could be cut off prior to the final firing, allowing for maximum beam expansion. Afterwards, bow and stern pieces could be fitted with cordage passed though drilled holes, and the seams caulked with pitch from resinous plants (Nicholson 1976c: 102). The hull could be caulked with a number of mixtures. The Quechua of Ecuador for instance, use a mix of shell powder and beeswax (Gorriarán 1987). An anonymous French chronicler indicates that the Caribs painted the stern of their canoes in red, using a "red earth" which was supposed to be the feces of a large snake called *Olubera* (in Cárdenas 1981: 193). Rochefort (in Cárdenas 1981: 372) reports that the Caribs at times painted mythical creatures on the freeboard (above the water line) of their canoes.

Protohistoric Caribbean aborigines had two types of dugouts: the canoe and the pirogue. Pirogues generally refer to the larger canoes used for inter-island voyaging or warfare. But size alone does not define a pirogue. The pirogue has a relatively wide beam, achieved through the process of controlled heating described above. Two other important traits of the pirogue are the use of wooden planks to increase the freeboard, and the presence of a keel for increased stability and control (Amich 1953: 349).

In Oceania, native boat builders achieve additional stability by the use of an outrigger (Bellwood 1979: 296). For increasing both stability and cargo space, two pirogues may be attached by two or more light beams, forming a double pirogue (O'Scanlan 1974: 422). Apparently, these last two techniques had limited or no use in the prehistoric Caribbean, as they are more typical of sailing canoes.

Loven (1935: 417) suggests that the protohistoric Tainos of the Greater Antilles had canoes, while the Caribs of the Lesser Antilles had pirogues. However, as McKusick (1970: 63) points out, Loven's reference on

Carib navigation was de la Borde, an 18th century French author By that time, Carib navigation had been greatly influenced by Europeans, including the use of sails, as reported by Labat (Cárdenas 1981 595)

At this point, there is no reason to assume that the preceramic peoples were any less adept than the Tainos or Caribs of protohistoric times If anything, the preceramic cultures may have been even more maritime-oriented than later agricultural peoples As discussed earlier, sails were probably introduced into the Caribbean in historic times but canoe-building is an ancient art

The building of a prehistoric canoe must have been a special thing, full of ritual and symbolic meaning, just as Puis (in Cárdenas 1981 215) observed for the Caribs in the 17th century Nicholson (1976 101) is right on the mark by suggesting that the occasion called for much 'drinking and merriment " A deep, near mystical feeling for the construction of watercraft is shared by all "primitive" boat builders, a feeling that is universally understood by mariners anywhere.

McKusick (1970 7) questions the feasibility of carving a 29m (96 ft.) long canoe out of a single log But here he is wrongly imposing modern forestal conditions on the prehistoric environment Seven thousand years ago, tall mahogany and cedar trees were commonplace both at the islands and on the mainland

In the early 1980s, a group of kayakers attempted to paddle from South America to Florida, following the Caribbean island arc At Mona Island, west of Puerto Rico, they reported that their only serious problem had been the occasional encounter with large pelagic sharks (Arturo Camacho, personal communication 1988) They had no problems with swells or currents, and fortunately no storms were encountered at sea

In 1987, four 15m (49 ft) long dugout canoes departed from the Andes to conduct a commemorative journey through the Amazon, and up the Caribbean islands to San Salvador in the Bahamas (Nunez 1987) In the winter of that same year, one of the canoes sank off Vieques Island and was promptly salvaged by local divers Weeks later, while conducting the marine archaeological survey for the Vieques-Culebra water pipeline, the author had the opportunity to inspect the canoe (Vega 1988)

Contrary to the tenets of experimental archaeology, iron nails and screws were used for thwart attachment The structurally loose seats and the narrow beam indicated that heat expansion had not been employed, as confirmed by a description of the building process published in a Spanish newspaper (Gorrarán 1987 25) Constructed by Quechua Indians in Ecuador this was a river canoe

In Vieques, the author's inspection revealed no hull damage resulting from collision or teredo (*Teredo navalis*) worms The canoe simply floundered Was this unfortunate accident solely the result of rough seas, possibly combined with poor seamanship? Or was the canoe not entirely suitable for offshore navigation?

It is possible that the pirogue is a genuine aboriginal invention, an adaptation of river canoes to oceanic conditions Beam expansion would make a more stable canoe. Riding low in the water, the ocean going canoe would require planking to reduce water intake A semi keel or perhaps simply a keel line could be carved out of the original log, for added stability and control Of course a full keel only makes sense in a sailing craft, as in the sharp hulls of Australonesian outriggers (Bellwood 1978 298, Figures 11 1 and 11 2), but a keel line would certainly improve the stability of a human powered canoe

It is interesting to notice that the Puerto Rican snow cone, traditionally served in a painted paper cup, is called *piragua*, which is Spanish for pirogue. Of course grated ice is not a Caribbean prehistoric treat, but the word *piragua* is. At face value, it seems quite a jump from linguistics to boat construction, yet, the relationship between the word and the paper cup is not entirely fortuitous, for in the age of sail a *piragua* was a keeled (pointed hull) canoe (Salas 1825, Talavera 1809, Vertiz 1799). Did the word have the same meaning in prehistory? If *piragua* simply means canoe, why would the aborigines also have the word *kanoa*? Two words for the same object?

According to Coll y Toste (1979: 249), the word *piragua* is a South American term for small boat, deriving from the root *pira* which in Guaraní means fish. In a more sophisticated study, Alvarez (1977: 123) concluded that *piragua* is a Taino word. This is supported by Taylor (1977: 20), who points out that the Taino word for water is *bagua* or *bahaua*, while the word for God is *Yúcahu Bagua Maorocoti*, roughly translated as Lord of the Manioc and the Sea, Who has no Father (Pané 1974: 21, 57).

In the author's opinion, the term *kanoa* was used by the Taino both as a generic term for all watercraft, and for designating the round-hulled canoe used for river and inshore navigation. On the other hand, the term *piragua* was used to designate a large, planked, possibly semi-keeled canoe for oceanic navigation.

In the final analysis, the question of whether canoes or piraguas were used by the precolumbian navigators can only be answered archaeologically, if we ever get lucky enough to find and properly excavate an ancient aboriginal canoe. To date, no aboriginal canoes have

been found in the Caribbean, not even prehistoric ones. Sharing the fate of numerous Maya codices, Taino canoes were often burned by the Spanish authorities in order to suppress aboriginal travel.

The maritime orientation of Caribbean aboriginal culture is confirmed by virtually all the European chroniclers from Columbus onwards. Numerous historic narratives speak of the great swimming, diving, fishing, seafaring, and maritime-hunting ability of the aborigines. For instance, Labat (in Cárdenas 1981: 596) describes how a barque sank off Martinique in 1669 with everyone drowning save for an Indian who stayed afloat for two and a half days without any support. In 1675, a large *pantouffier*, from the description clearly a great hammerhead shark (*Sphyrnidae*), fatally wounded a boy at Basseterre, St. Kitts. Labat narrates how a Carib fisherman dove and killed the shark with bayonets, tied a rope to its tail, and towed the "monster" to the beach, where the dead boy's leg was retrieved from the shark's stomach.

Canoes were the single most important objects in the prehistoric conquest of the Caribbean, and it is deeply symbolic that they may also have been an important encouragement for the historic conquest as well. In a fascinating and seldom discussed passage, de Las Casas (1957: 47-48) indicates that aboriginal canoes on occasion drifted to the Azores, Madeira and Canary Islands, adding credence to the mysterious legends of lands beyond the great Ocean Sea.

Among the sailors who reported on these mysterious "logs" were Pedro Correa, Columbus' brother-in-law, who saw one at Puerto Santo (Madeira Islands), and Martín Vicente, who picked one up 450 leagues (1350 miles) west of Portugal's Cape St. Vincent. De las Casas describes some of these finds as *maderos labrados* (worked or carved logs), but he

also refers to them as *canoas* and *almadias* , the latter being the old Hispano Arabic word used prior to the inception of the Caribbean term (Guillen 1951 25) There is no doubt that these were New World canoes

Cultural Ecology

We do not think a lazy man can commit murders nor great thefts nor lead a mob. He would be more likely to think about it and laugh And a nation of lazy contemplative men would be incapable of fighting a war unless their very laziness were attacked.
John Steinbeck (1976 186)

But it is good that we do not have to try to kill the sun or the moon or the stars. It is enough to live on the sea and kill our true brothers.
Ernest Hemingway (1955 67)

The Pleistocene-Holocene transition was a time of great ecological and cultural transformations Due to either climatic changes or human over kill, or both, numerous species of large land mammals became extinct In the Americas, the megafauna included mastodon, mammoth, megatherium, mylodon, paleolama, camelid, hippidium, toxodon, cave bear, saber-toothed tiger, dire wolf, glyptodon, etc Many of these animals were already extinct or nearly so by the end of the Pleistocene, some persisted until the mid-Holocene (Cockrell 1980 138, Lynch 1978 478)

The archaeological record indicates that by 9000 B P , New World preceramic cultures intensified their reliance on gathering and exploitation of coastal resources (Cohen 1977 251) By 7000-5500 B P ,if not earlier, permanent settlements appeared on estuarine environments (McNeish 1967 327) Overall, the early Holocene was a time of relatively rapid sea level rise, in the order of 8mm (31 in) per year (Kennett, 1982 270) Ruppé (1980a 36) has suggested that coastal sites were formed during stillstands, periods of a temporary halt in sea level fluctuations In times of

rapidly rising sea level, coastal villages may have formed on a semi permanent basis, either moving progressively landward or to new sites nearby. Certainly this would have had a tremendous impact on site formation, in terms of midden size, stratigraphy, and horizontal displacement.

The technology of canoe-making allowed a maritime-hunting lifeway as complex in ritual and technique as any land-based, Pleistocene hunting tradition. The marine prey of Circum-Caribbean hunters included manatees, seals, sea turtles, sharks, rays, and stranded whales. Coastal fauna included birds, iguanas, small mammals, tortoises and shellfish (Figueredo 1978; Olsen 1982). A variety of wild plants and fresh and salt water fish would complete the diet (Wing 1968).

The seafaring hunters would have been characterized by two primary tendencies. The first tendency would be to move when the animals they hunted became scarce, thus the entry of preceramic peoples into the Caribbean. The second tendency would be a progressive move from marine big game to small coastal game, and a further intensification of shellfish collecting (Yesner 1980: 734). This second tendency may have led the coastal hunters to greater permanency in their settlements.

The primary prey may have been the manatee, a large mammal found in both fresh and salt water. Attaining a length of 4.2 m (14 ft.), manatees were hunted in prehistoric and protohistoric times throughout the Circum-Caribbean, Florida, and the Gulf of Mexico. Manatees belong to the order of Sirenia, comprising five modern species of aquatic, herbivorous mammals: 1) the dugong (*Dugong dugon*), ranging from the east coast of Africa to Southeast Asia, Australia, and the Solomon Islands; the African manatee (*Trichechus senegalensis*), found in the coasts and rivers of West

Africa, from Senegal to Angola, 3) the Amazon manatee (*Trichechus inunguis*) found in the Amazon and other South American rivers, 4) the West Indian manatee (*Trichechus manatus*), found in Central America the West Indies, and Florida, which some researchers divide into a Caribbean and a Florida sub species, and 5) Steller's sea cow (*Hydromalis gigas*), possibly hunted to extinction, although there are reports of survival (Heinsohn et al 1979 49)

The author has discussed manatee biology, ecology, and prehistoric hunting techniques elsewhere (Vega 1981, 1985), and will only summarize here the hunting data For an annotated bibliography on Sirenia, see Whitfield and Farrington (1975)

Sirenians are endangered everywhere, but some aboriginal societies continue to hunt them as their primary source of meat In Australia, a harpoon and rope are still used to hunt the dugong (Heinsohn 1979 48) The same method has been used into modern times by the Miskito Indians of Nicaragua (Barrett 1935 217) The Maya of Yucatán also used a harpoon and line for manatee hunting (Baughman 1948 237) The Omagua Indians hunted the Amazon manatee with shell-tipped harpoons (Hemming 1978 116) Manatee hunters of the Orinoco River used a double-barbed harpoon tied to their canoes with a strong rope of manatee hide (Baughman 1946 237)

In the Corentyn River, between Guyana and Surinam, Arawak Indians used three-pronged arrows to hunt manatees On Nicaragua's Indio River, manatees are traditionally hunted at night (Barrett 1935 216) Some Australian aborigines use nets to capture dugongs (Coffey 1977 204) In Guyana, an entire Indian village may engage in constructing underwater stockades to trap manatees and turtles in strategic river

channels, drowning captured manatees by placing wooden pegs in their nostrils (Jong 1961 3) Pedro Martir (in Arrom 1972, Underhill 1982) reports of a Greater Antillean Taino chief who netted a young manatee and raised it as a pet

José Gumilla a Jesuit missionary who lived among the Indians of the Orinoco River in the late 18th Century, describes how hunters would transport a dead manatee Leaping into the water, they would tilt their canoe in order to flood it, then they would push it under the dead manatee, bail out the water and paddle home (Baughman 1946 237) All sources report the uses of canoes Excluding river environments where nets could be waded or swum across, the canoe was an indispensable tool for manatee hunting

Manatee bones have been found in archaeological context throughout the Caribbean, including the sites of Calmanes III, Cuba (Navarrete 1983 113), Sabanete de Juandolio and El Porvenir/Serrallés in the Dominican Republic (Velez and Ortega 1976 153, 160), Anadel, Dominican Republic (Rainey 1940 126), Cueva María de la Cruz, Puerto Rico (Alegría et al 1955 117), Ostiones, Las Cucharas, Pitahaya and Playa Blanca, Puerto Rico (Rouse 1959 387, 396, 541, 551), Isla Verde, Puerto Rico (Vega 1981 52), Suazey sites in Granada (Wing 1968 105), Chec, St Lucia (Ray 1960 412), etc. Charlevoix (in Fewkes 1907 56) mentions a Haitian cacique (chief) by the name of Manatibex.

Observations of manatees in historic times have been made by Columbus (Colón 1964 111), Ovando (in Sauer 1969 56), Martir and Oviedo (in Arrom 1972 33), Carvajal, de Landa, Acosta, Gumilla, Raleigh, Harcourt, Dampier, Exquemeling, Clavijero, Humbolt, Wallace Bates (in Baughman 1946), and Labat (in Ray 1960 413)

When the first prehistoric seafarers reached the West Indies, large manatee herds were commonplace. In 1893, a dugong herd encountered in Moreton Bay, Australia, reportedly extended over an area 4.8 km (3 miles) long and 274 m (300 yards) wide (Heinsohn et al. 1978). Unquestionably, similar manatee herds once lived in Caribbean waters. Seven thousand years ago the manatee was to the Caribbean what the elephant was to Africa and the bison to North America.

Another important prey of Caribbean maritime hunters was the sea turtle. Five species were available: 1) the loggerhead turtle (*Caretta caretta*), 2) the Atlantic Ridley or Bastard turtle (*Lepidochelys* sp.), the Hawk's bill turtle (*Eretmochelys imbricata*), 4) the green turtle (*Chelonia mydas*), and 5) the leatherback or trunk turtle (*Dermochelys coriacea*). Turtle bones have been found in numerous archaeological sites, including Pertales and Cabo San Antonio, Cuba (Rainey 1940: 140), Samaná Bay Caves, Dominican Republic (Rainey 1940: 125); Las Cucharas, Puerto Rico (Rouse 1952: 387); Cayo Cofresí, Puerto Rico (Maggiolo et al. 1975: 29), Ensenada Honda, Puerto Rico (Tronolone et al. 1984: 3-11), Isla Verde, Puerto Rico (Vega 1981: 58), Magens Bay, St. John (Sleight 1962: 44), etc.

In his 1542 expedition to the Amazon, Francisco de Orellana observed that the Omagua Indians "raised thousands of turtles in ponds beside each house" (Hemming 1978: 15). In Nicaragua, the modern Miskito use nets to capture sea turtles, but the traditional method was to hunt them with wooden shafts (Nicholls 1977: 97). Turtles could also be hunted with bow and arrow. The Taíno of the Greater Antilles used an ingenious system of tying a line to a remora or suckerfish (*Echeneidae*), letting it attach to the turtle's plastron or breastplate, and then pulling both back to the canoe (Sauer 1969: 82, 183). Finally, turtles could be captured seasonally

(summer) on the beach, as they came ashore to lay their eggs (Wing 1968 104)

Stranded whales and porpoises were a potential source of meat to preceramic hunters The use of stranded whales in the European Mesolithic has been recorded for Tardenoisian, Larnian, Obanian, and Ertebølle cultures (Cohen 1977 124) Humpback whales (*Megaptera novaeangliae*) appear regularly in the Caribbean from January through March (Erdman et al 1973 2) These migrations are necessary for survival, for the young calves lack the blubber thickness necessary to withstand the icy Artic and Antarctic waters (Adams 1971 55) Undoubtedly, the colder climate of the late Pleistocene-early Holocene resulted in an increased Cetacean presence in the Caribbean

Other whales that are regularly seen in Caribbean waters include rorquals or fin whales (*Balaenoptera* sp), Cuvier's beaked whales (*Ziphius cavirostris*), pilot whales (*Globicephala macrorhynchus*), and occasionally sperm whales or cachalotes (*Physeter catodon*) Bottlenose dolphins (*Tursiops truncatus*) and common dolphins (*Delphinus delphis*) are frequently seen, with occasional sightings of Risso's dolphins (*Grampus griseus*), spotted dolphins (*Stenella* sp) and killer whales (*Orcinus orca*) In 1975, a pack of twenty-five killer whales or orcas attacked a large whale near Grampus Shoals, SE of Culebra Island (Erdman 1970 638)

Whale strandings are relatively common in the Caribbean In 1961 a beaked whale was stranded off La Parguera, on the south coast of Puerto Rico, followed by five strandings in 1965 Another beaked whale was stranded in 1964 at Petillo Beach east of Ponce (Erdman 1970 637) In 1966 a sperm whale was stranded off Punta Cadena, west coast of Puerto

Rico, that same year, another sperm whale was stranded near Villas del Mar, Dominican Republic (Erdman et al. 1973: 4).

The use of whales by Caribbean preceramic hunters is proven by a worked vertebra found at El Porvenir/Serrallés, Dominican Republic. The deposit also contained manatee, sea turtle (*Chelonia mydas*), various species of fish and shellfish, ray (*Aetobatidae* sp.), hutia (*Plagiodontia* sp.), and possibly crocodile (Veloz and Ortega 1976: 154).

In the 19th Century, New England whaling vessels regularly hunted sperm whales, pilot whales, and humpbacks in Caribbean waters. Late in the century, at least ten native whaling stations arose in the islands. Using small, open sailboats 7.6m (25-26 ft.) long, the whalers would chase their prey with wrought iron harpoon and "bomb lance," an explosive brass cylinder fired from a shoulder gun (Adams 1971).

It is extremely unlikely that Caribbean prehistoric hunters actually set out in pursuit of whales, but then again every age has its daredevils. A far more realistic scenario is the hunters taking advantage of stranded whales, killing the animals with flint-pointed spears such as those of the Cordillera Central complex of the Dominican Republic (Veloz and Ortega 1976: 153, Figures 60-63).

The preceramic aborigines probably hunted the West Indian monk seal (*Monachus tropicalis* Grey), which in historic times ranged throughout the Caribbean Sea and the Gulf of Mexico (Coffey 1977: 190). Although generally regarded as extinct, apparently a few individuals have been sighted in recent years (Soto 1988: 79).

From the above discussion, it is clear that the Caribbean and other tropical areas of the world had the resources for a maritime hunting tradition. Just as there were Pleistocene big game hunters on the

mainland, there may well have been early mid Holocene big-game hunters on Caribbean waters These maritime hunters may have been the first settlers of the Antilles

Sloths were the largest Pleistocene land fauna to inhabit the Greater Antilles According to Marcano (in Veloz and Ortega 1976 163), eight species of sloths lived in Cuba, six in Hispaniola, and two in Puerto Rico, including the genera *Megalocnus* , *Mesocnus* , *Parocnus* , and *Acratocnus* Sloths were common in the American mainlands as early as the Pliocene (2 to 13 million years B P), which suggests a Caribbean migration well before humans For Raggi (1973 135) and Marbán (1984 28), the presence of these extinct edentates suggests a Caribbean land bridge with Florida or Honduras But if a land bridge existed how do we account for the lack of other large Pleistocene megafauna in the Greater Antilles? For instance, in Trinidad, which was connected to South America until 10,000 B P , mastodon fossils have been found at Pitch Lake, Forest Reserve, and Los Bajos (Harris 1976) Similar fossils have never been found past the Tobago Basin.

Simpson (in Rouse 1970 3) has suggested that the indigenous fauna of the Greater Antilles is the product of accidental rafting from the Magdalena and Orinoco Rivers, in Colombia and Venezuela respectively If we take into consideration the prevailing NW currents of the Caribbean, this hypothesis explains the presence of sloths in the Greater Antilles, and their absence in the offshore Lesser Antilles Although some species of sloths were fairly large animals, it is quite possible that they would be rafted during ebb tide downriver On the other hand, it is virtually impossible that mastodons would be transported in similar fashion.

The migration routes of island preceramic cultures is a mystery, and it will continue to be so until sufficient early sites are available to generalize. If the hypotheses presented in this dissertation are correct, then most of the early sites that we need to find are beneath the sea.

No completely submerged preceramic sites have been excavated in the Caribbean, and apparently none have been located. So far, Caribbean preceramic sites have been found on uplifted or prograding coasts, or in small islands and keys separated from the parent island; others are inland workshops with only an indirect relationship to the coast. The rest are late preceramic sites, some of which are close to or within the intertidal zone (Veloz et al. 1975). It is no coincidence that many of the early preceramic sites have been found in Hispaniola (Ortega and Guerrero 1981, Veloz and Ortega 1976), an island that has experienced localized uplift well into the Pleistocene (Alexander 1985: 181).

South, Central and North American origins have been proposed for the preceramic peopling of the Caribbean (Davila 1985; Cruxent and Rouse 1969; Pina 1971; Raggi 1973; Rouse 1964, etc.). Bullen (1976: 14) has argued against a Florida origin on the basis of the Gulf Stream. The Stream segment that separates Florida from Cuba and the Bahamas is the Florida Current, with a velocity of five knots (mph), and a transport rate of about 30 million cubic meters of water per second. Further north, the Stream runs somewhat slower, but the transport rate increases to over 150 million cubic meters of water per second, roughly 100 times the flow of all the rivers in the world put together (McLeish 1989: 47).

Certainly the Gulf Stream is an awesome "river in the sea," but it would be a mistake to see it as an insurmountable barrier to southbound preceramic migrations. First, a lower sea level would reduce both the

volume and speed of the Stream, second, the greater size of the Bahama Islands would reduce the crossing by a half in some places. Contrary to the usual argument, the easier crossing would not be from the Florida Keys to Cuba, but rather from East Florida to the Little Bahama Bank, beneath the 27th parallel. Once in the Bahamas, the prehistoric seafarers would have easy access to Central Cuba and Hispaniola via Turks and Caicos, Mouchoir Bank - Silver Bank. Without any intention of participating in the "preceramic route guess," it is worth mentioning that a number of submerged, early sites have been discovered in the Vero Beach area, East Florida (Cockrell 1980). At present, the author is not inclined towards any route in particular. Few early sites are known and Caribbean paleoenvironmental reconstruction is in its infancy, as is the cultural ecology of tropical, maritime hunter-gatherers (Yesner 1980: 746).

CHAPTER 4
COASTAL GEOARCHAEOLOGY, PUERTO RICO

Physiography and Climate

After one has lived in these latitudes long enough the changes of the seasons become as important there as anywhere else and Thomas Hudson who loved the island did not want to miss any spring nor summer nor any fall or winter
Ernest Hemingway (1971 4)

There is a pleasure in the pathless woods
There is a rapture on the lonely shore
There is society where none intrudes,
By the deep Sea, and music in its roar
George Gordon Lord Byron (1966 74)

Puerto Rico is approximately 161 km (100 miles) long and 56 km (35 miles) wide The island is divided into a northern and southern half by a central mountain chain of volcanic and plutonic igneous rocks (Mitchell 1954 85) About 40% of Puerto Rico is mountain terrain, with 35% hill, and 25% level (Picó 1974 26) The highest elevation is that of Cerro Punta, towards the center of the island, with an altitude of 1,338 m (4,390 ft) Prominent peaks also rise on the northeast section of the island, at the Luquillo Range, reaching a maximum elevation of 1,074 m (3,532 ft)

The insular shelf is narrow to the north, and wide to the east and southwest (Figure 8) The composition of the coastline ranges from unconsolidated sediments to limestone and igneous formations Of 740 km of coast, 20% are beaches, which are generally short and divided into separate systems with little interaction (Morelock and Trumbull 1985 187)

Tides average about 30 cm (1 foot). Shorelines exhibit great variation, with five generalized types in six separate stretches (Kaye 1959: 51).

Sea surface temperatures range from 82.5°F in September to 77.9°F in February. Largely due to the moderating effect of the sea, Puerto Rico's median temperature of 79°F at sea level varies within 5.9°F throughout the year (McDowell 1969: 1). Most rainfall and river discharge is to the north, with a semi-arid south coast. Rain is most abundant at El Yunque Rain Forest on the northeast, with over 5 m (200 inches) of annual rainfall. The southwest is the driest part of the island, with an average annual rainfall of 1 m (40 inches).

Puerto Rico's position on the northeast corner of the Caribbean Basin exposes it to the mainstream of the Great Northern Equatorial Current (GNEC). This powerful ocean current originates off the West African coast and crosses the Atlantic in clockwise fashion, veering north as it touches the Caribbean. The influence of the GNEC provides an additional element of humidity to the island's tropical climate. The sea-land breezes generally blow offshore at night and at dawn (when the land is cooler than the surrounding ocean), and inshore during the daytime (when the sea is cooler). The island is also affected by hurricane winds, which are frequent in the Caribbean during the warmest months, from June to November. In general, hurricanes follow the WNW path of the trade winds. The coastal plains are narrow and flanked by hills. The central mountain range slopes gradually to the north, and abruptly to the south.

There are approximately 1300 streams, of which seventeen (17) form true river systems. The largest rivers flow to the north, where low drainage results in swamps and marsh lagoons. On the interior of the island are numerous wet and dry cave systems. Soils show a high degree of

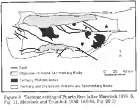


Figure 8 Tectonic setting of Puerto Rico (after Morelock 1978 5, Fig 11, Morelock and Trumbull 1985 188-88, Fig 29 1)

Figure 9 Location of prehistoric sites used for the study

variation, with only about 6% or 129,000 acres classified as first rate. At present, about 75% of the island's soils are considered of inferior quality, located mostly in the mountainous interior (Picó 1974: 214).

Puerto Rico is an excellent setting for the study of sea levels. As Kaye (1959b: 51) has pointed out, the island is "exceptionally well suited" for the study of eolianite and beachrock. These lithified sand formations are both resistent and highly visible, and may be used to trace the exact location of relict shorelines (Kaye 1959b: 67). Moreover, eolianite and beachrock provide accurate "signatures" of sea level in the form of nips and tidal terraces, and may be radiocarbon dated (McLean 1967, Milliman and Emery 1968).

The island has a wide variety of coastal geomorphological settings, yet is small enough to be sampled in a single project. The north coast is characterized by high-energy beaches and limestone cliffs, in contrast to the south's low-energy, predominantly mangrove coastline. Both the east and west ends exhibit fault control (Morelock and Trumbull 1985, Pilkey 1976). A rich karst topography provides additional evidence of marine transgression in the form of submerged speleothems.

Puerto Rico has a long prehistory characterized by coastal cultures and one of the longest historic periods in the New World, with rich documentation and widespread construction of coastal installations (Hoffman 1988, López Cantó 1975, Vila Vilar 1974). Early cartographic and architectural material abounds, including nautical charts and fortification profiles with mean sea level.

The small tidal range of 30 cm (1 foot) reduces the inter-tidal zone at any given time period to a narrow strip, somewhat simplifying the archaeological measurement of coastal change. Finally, the island's

geomorphology is not further complicated by postglacial rebound, and adequate to excellent diving conditions are found nearly year-round

Geomorphological Markers

It is advisable to look from the tide pool to the stars and then back to the tide pool again
John Steinbeck (1976: 216)

Today fish shelter from the currents where men once sheltered from the rain.
Nicholas C. Flemming (1972: 164)

The Caribbean is characterized by a number of geological formations closely related to sea level. A complete listing of these features is provided in Chapter 1 (Research Domains). In the course of field work, the author has had the opportunity to make extensive observations of some of these geomorphological markers of coastal change, particularly eolianite and beachrock.

The coastal geomorphology of Puerto Rico is formally discussed by Guilsu and Glass (1957), Kaye (1959a, 1959b), Mitchell (1954a, 1954b), Morelock (1978), Morelock and Trumbull (1985), and others. We shall now take a brief look at some geomorphological considerations pertinent to the study.

Eolianite

Eolianite is wind-deposited sand cemented by calcium carbonate ($CaCO_3$). In Puerto Rico, these cemented or lithified dunes are prevalent along the north shore, on occasion reaching a height of 30 m (100 ft.) or

mere San Juan's impressive fortresses of El Morro and San Cristobal rise atop eolianite, of which four generations of cemented dunes are recognizable (E1-E4), each separated by a layer of ancient soils or paleosols (Kaye 1959a: 35). The islets and rocks off the north coast, from Camuy to Loiza, are the remnants of submerged cemented dunes of late Pleistocene origin (Kaye 1959b: 80; Pilkey 1978: 95). Many of Puerto Rico's coral gardens inspected by the author are not true coral reefs, but rather patches of submerged eolianite covered by a thin veneer of coral.

Cemented dunes are weathered by a complex process involving frontal attack by waves, undermining of sand beneath the cemented dune by surf, the eating and boring habits of periwinkles (*Littorina ziczac* Gwelin and *Tectarius muricatus* Linné), barnacles (*Balanus balanoides*), chitons (*Chiton tuberculatus*), and sea urchins (*Echinometra lacunter* L.), biochemical activity in tide pools, and the milling action of surf-propelled pebbles.

Looking at the distribution of cemented dunes in nautical charts and aerial photographs, it is clear that much of Puerto Rico's north coast has evolved from a relatively straight eolianite shorefront to an arcuate coast. This is the product of arcuate wave patterns diffracted by breaks in the eolianite ridge, an important process for understanding the immersion of at least one archaeological site, that of Isla Verde (Vega 1981: 34), discussed in some detail below.

Diving half a mile or so off the north coast, the author has seen cemented dunes starting at 7 m (23 ft.) beneath the surface of the ocean and plummeting to a depth of over 40 m (131 ft.). These submerged eolianite formations mark a Quaternary paleocoastline far less explored than the Amazon—ecology uncertain, occupants unknown.

Beachrock

Beachrock is cemented beach sand or shingle. As in eolianite, the cementing agent is calcium carbonate, although rare instances of cementation by iron oxides have been reported by Kaye (1959b: 66). Beachrock forms a hard pavement along the shore (strandline); when found underwater, it clearly indicates that marine transgression has taken place. The pavement generally dips at a slight angle towards the sea, and may reach a width of 60 m (200 ft.) or more. Frills or grooves perpendicular to the shore are often formed on the pavement, produced by mechanical abrasion (McLean 1967). Like coral, beachrock is a formation of tropical and sub-tropical seas. The distribution of beachrock formations in Puerto Rico is discussed by Gillou and Glass (1957) and Kaye (1959b).

Off Puerto Rico, numerous submerged beachrock pavements may be observed by snorkel and scuba diving. Off Stop 8, at a popular surfing spot just west of El Escambrón Sports Complex, San Juan, the author has traced an underwater beachrock pavement that runs for over 300 m (1,000 ft.). Kaye (1959b: 118, Figure 55) also reports on it. While conducting the Vieques Sound Marine Archaeological Survey, the author found a beachrock pavement at a depth of 19 m (62 ft.), four miles from the nearest land (Vega 1986: 45).

Sea Caves and Karst Caves

Sea caves are formed by wave action in high energy coasts, and finding them underwater clearly indicates that marine transgression has taken place. The author has explored sea caves off Costa Azul (Luquillo), Bajura de los Cerezos (Isabela), Islote (Arecibo), Culebra

Island, and Mona Island Other divers have reported undersea caves at Tourmaline Reef (off Mayaguez), La Parguera, Vieques Island, etc

Karst caves are formed by the weathering and erosive processes of acid-charged water on soluble-rock terrain, including limestone, dolomite, marble, and gypsum Puerto Rico has an impressive karst topography, with an estimated 2,000 caves and at least one 13 km long system at Camuy (Alfonso 1981, Girón 1973, Metke 1973) At Guajataca Beach, the author discovered a small karst cave that is now beneath the sea In the smallest of two rooms, which should only be explored by experienced cave divers in the calmest sea, fish swim amid short stalagmites and columns

Archaeological Sites

"I've always wanted to see a Martian," said Michael. "Where are they Dad? You promised."

"There they are " said Dad, and he shifted Michael on his shoulder and pointed straight down

The Martians were there Timothy began to shiver

The Martians were there--in the canal- reflected in the water Timothy and Michael and Robert and Mom and Dad The Martians stared back at them for a long long silent time from the rippling water

Ray Bradbury (1967 181)

One white skull and seven dry bones
On the margin of the stones,
Where a few gray rushes stand,
Boundaries of the sea and the land
P B Shelley (1978 318)

The coast of Puerto Rico is rich in aboriginal sites All four coasts and all large offshore islands possess evidence of prehistoric occupation Numerous archaeological studies have been undertaken since the pioneer work of the late 19th and early 20th centuries including the early research by Fewkes (1907) and de Hostos (1919), and the extensive archaeological surveys by Rainey (1940) and Rouse (1952a, 1952b)

Following a literature search and interviews with various archaeologists and coastal dwellers, beach and marine surveys were conducted by the author along Puerto Rico's four coasts. Over 100 snorkel and scuba dives were conducted, ranging from solo dives to groups of up to six divers, generally following transect lines perpendicular to the shore. The length and spacing of transects varied according to visibility and bottom contour. These simple operations included the use of underwater slates, measuring tapes, PVC stadia rods, compass, and underwater camera and video. In the case of Isla Verde Site, a more complex field strategy was involved, including underwater excavation with a water dredge and PVC grids, as well as aerial photography analysis (Vega 1981).

Coastal and submerged sites were mapped into the U.S. Geological Survey Quadrangles, using the Puerto Rico 2000 meter grid coordinate system. Due to the nature of the research, the standard presentation of contour intervals in meters vs water depth in feet was a subtle visual hindrance to the blending of submerged and subaerial geomorphological interpretation.

In some cases, access to beaches proved to be a logistical problem. As an inheritance from Spanish law, the beaches of Puerto Rico are public lands (Coastal Zone Task 1972: 59). However, due to the nature of Puerto Rico's beaches, which are generally small and segmented by headlands, lagoons and rivers, access often requires passing through private lands, or the use of a boat. Today, Puerto Rico's coastline is segmented by barbwire and *No Entre* signs. On occasion, the barbwire cuts across the beach and into the sea, in violation of the law. Much of the coastal zone outside the metropolitan area belongs to absentee owners, further complicating the process of acquiring permits for archaeological surveying.

A total of twenty nine prehistoric coastal sites in Puerto Rico were chosen for the study (Figure 9) In terms of location, the sites range from over 1 km inland to submerged (Table 2) Many of the sites were surveyed or visited by the author generally including restricted surface collecting Most of these sites pertain to the Ostionoid series or culture, which has been radiocarbon dated between 800 and 1200 A.D (Vescelius 1979) Probably originating in southwestern Puerto Rico, Ostiones culture spread to all four coasts and significant portions of the island's interior, eventually expanding into the Dominican Republic and the Virgin Islands, and exerting an overall sphere of influence as far south as Trinidad (Bullen and Bullen 1976 6) The Ostiones people were agriculturalists who also consumed outstanding quantities of shellfish Indeed, this cultural phase of Caribbean prehistory was originally labelled Shell Culture by Rainey (1940)

The term Ostiones itself is Spanish for oyster The type site of the series is at Punta Ostiones, Cabo Rojo, virtually a small peninsula made up of shell discard In addition to shellfish and root crops, Ostiones subsistence included maize, fruits, nuts, fish, lobster, sea urchin possibly octopus, waterfowl, manatee, turtle, tortoise, iguana, small land mammals, etc It is clear from the archaeological record that these people exploited the sea, the shore, rivers, mangrove, and inland ecozones

Compared with previous as well as later prehistoric ceramic traditions in Puerto Rico, Ostiones pottery is rather plain, more functional than artistic Diagnostic traits include loop handles, thickened rims, annular bases, red slip, straight sides flaring outwards, vessel walls averaging 0 6 cm (2 in) thick, head lugs, incision, and boat-shaped

TABLE 2

Description of Prehistoric Sites Used in the Study

	Site and Coast	Relation to Sea Level	Date B P	ESM
1	Isla Verde (N)	Submerged 0 2 m	1200-800	200
2	Balneario Isla Verde (N)	Sherds on beach	1200-800	10?
3	Merle de la Cruz (N)	Prograded coast-river	1920*	+850
4	Punta Embarcadero (N)	Intertidal	1440-1240*	-20
5	Aguas Prietas (N)	Near shoreline	1200-800	-10
6	Cabezas de San Juan (E)	Tidal lithified burials	1200-800	15
7	Ensenada Honda (E)	On islet	1100-700	-30?
8	Playa Blanca (E)	On islet	?	-40?
9	Petroglyphs Caño N (E)	Intertidal	1100 700	-20?
10	Petroglyphs Caño S (E)	Partly submerged-islet	1100 700	-30?
11	Cayo Santiago (E)	Islet	1000 600	400
12	Jobos (S)	Inland midden	3000?	+1 3k
13	Cayo Cofresí (S)	Partly submerged-islet	2245 2275*	-304
14	Cayito (S)	Intertidal	700*	-15
15	Bay of Montalva (S)	Islet	1200-800	-200
16	Papayos (S)	Inland midden	2500?	+300
17	Magueyes (S)	Islet	1300-900	-100
18	Corosa (SW)	Inland midden	3000?	+1k
19	Boquerón (W)	Slightly prograded	1600 900	+50
20	Ostiones (W)	Slightly prograded	1545 900*	+10
21	Cayo Ratones (W)	Submerged 0 5-2 m	1400-800	427
22	Joyuda (W)	Intertidal	1200 700	20
23	Petroglyphs, Ensenada (W)	Intertidal	?	10
24	Mar Chiquita (N)	Intertidal	1200-800	10
25	Tortuguero (N)	Intertidal	1200-800	10
26	Petroglyphs, Maisabel (N)	Intertidal	1000-700	-10
27	Playa Cerro Gordo (N)	Intertidal	1200-800	-10
28	Punta Mameyes (N)	Intertidal	1200-800	-10
29	Punta Corozo (N)	Intertidal	1200-800	10

ESM=Estimated Shoreline Migration

* Radiocarbon Date

For site locations, see Figure 9

vessels (Rainey 1940: 15; Rouse 1964: 509, 1986: 134). Thick clay griddles for baking cassava are commonplace, clear evidence that these people were agriculturalists.

Ostiones culture foreshadowed the rise of the protohistoric Taino chiefdoms. It is at the Ostiones phase of development that the first ceremonial plazas or *bateyes* were built. In Puerto Rico, ceremonial plazas have been found in Utuado, Lares, Adjuntas, Barranquitas, Orocovis, Jayuya, Ponce, Cabo Rojo, and Mona Island. Alegría (1951) and Fernández Méndez (1979: 69) suggest that these plazas represent a direct link with Central America or Mesoamerica, as the Antillean plazas were used for playing a ball game closely resembling the Maya *Pok ta pok* and the Mexican *Tlachtli*. Velez Maggiolo (1972) sees a stronger influence from South America, where the Otomaco and other aboriginal societies of Venezuela played a ball game as well. In its many variants, the ball game was played by a wide assortment of New World cultures, including the Hohokam of the North American southwest (Lipe 1978: 344).

The cult of three pointed stone or shell amulets antedates Ostiones culture, but it was at this phase that this enigmatic cult expanded tremendously throughout the Lesser Antilles (Bullen and Bullen 1976: 6). Symbols of *zemis* or supernatural entities, these three-pointers gradually evolved into highly sophisticated Taino sculptures of animals, gods, and geometric designs.

Whatever its nature and limitations, the influence that Ostiones culture exerted throughout the islands required political strength and considerable population density. In a complex, as yet poorly understood fusion of internal trends (Ostiones culture) and external influence (Maya

culture), the Taino chiefdoms of the Greater Antilles came into being. We shall now look at selected coastal sites in some detail.

Isla Verde

Isla Verde is a ceramic site submerged off Punta el Medio, 8.8 km east of San Juan (North Coast-Carolina Municipio). The site is located in shallow water between an inshore reef and Puerto Rico's north coast. Following a preliminary survey in 1978, underwater test excavations were conducted by the author in 1980 (Vega 1981). The site has been subsequently revisited for additional observations up to the present.

For the 1980 field work, two datum points were established. Point A on the southwest corner of a small islet at the end of the inshore reef, and Point B on the northernmost tip of a seawall on the coast. A segmented base line was run between datums, and soundings taken with a stadia rod at 2 m intervals. This yielded a maximum water depth of 2.4 m and an average depth of 2.4 m. Five 2x2 m test pits were excavated underwater with a water dredge, followed by a smaller 80x40 cm test pit excavated by shovel on the islet.

The underwater excavations clearly revealed a compact midden submerged in place. Located at the median point of a compound lunate embayment, the site was submerged as the embayment expanded (Vega 1981: 34-49). During transgression, the midden was protected from direct surf by both the inshore reef and the islet.

The 1980 excavations yielded Ostionoid and a few Elenoid pottery shards, petaloid stone celts made of mudstone and volcanic breccia, shell picks and gouges, and human bones. The more recent Elenoid pottery

sherds were recovered from the surface of the sea-floor but not below suggesting some stratigraphic coherence One anthropomorphic motif was found a small flat face in reddish clay This face is similar to those carved in ceremonial stone celts of the later Taino culture (Rouse 1964 509, Fig 15) A total of eleven cassava griddle or *burén* sherds were found, indicators of agriculture The diet also included manatee (*Trichechus manatus*), sea turtle (*Chelonia mydas*), fresh water turtle (*Chrysemis*), porcupinefish (*Diodontidae*), parrotfish (*Scaridae*), and of course shellfish Common univalve shellfish included *Cassis tuberosa* Linné, *Strombus gigas* L , and *Cittarium pica* L Common bivalves included *Anodontia alba* Link, *Arca Zebra* Swainson, *Phacoides pectinata* Gwelin, *Trachicardium egmontianum* Shutt, and *Lucina pensylvanica* L

Reconstruction of the paleocoastline indicated that the islet was part of the prehistoric shore, the mid point of a smaller lunate embayment As the embayment expanded, the islet was segregated and the midden submerged. With the sea to the north and a larger San José Lagoon to the south, the vilage was practically surrounded by water In modern times, at the eastern end of the embayment, Torrecilla Lagoon was opened to the sea, killing much of the area s once famous coral gardens

Balneario Isla Verde

This is a small Ostionoid site at Isla Verde Beach, approximately 500 m (1640 ft) S-SW of Boca de Cangrejos (North Coast-Carolina) The site is mostly covered by the road pavement of the public beach, but sparse pottery sherds may be seen at the beach scarp adjacent to the

pavement. The site appears to be partly eroded, but diving inspection off the beach revealed no ceramics or shell discard.

Maria de la Cruz

Maria de la Cruz is a multi-component site located east of the Loiza River, Rio Grande (North Coast Loiza). In 1948, Alegria conducted test excavations there, finding a preceramic level beneath a ceramic level of Cuevas white-on-red pottery (Alegria et al. 1955: 114). Animal bones, many of them burned, were present in great quantities. Tools from the preceramic level included hammerstones, shell scrapers, pebble grinders, choppers, etc. In 1954, additional excavations by Alegria and Nicholson yielded two burials in poor condition (Alegria et al. 1955: 117). That same decade, Kaye (1959: 115) used the site to date fossil beach ridges in order to estimate the rate of beach advance near the Loiza River outlet. For Puerto Rico, if not the entire Caribbean, this was the first geomorphological study in which archaeological sites were used as markers of shoreline migration. The geoarchaeological implications of this Maria de la Cruz Site are discussed in Chapter 5.

Punta Embarcadero Monserrate

The site of Punta Embarcadero is located in Barrio Monserrate (North Coast Luquillo). The site, also known as Luquillo or Monserrate, is on a sandflat near a small stream at the east end of Luquillo Beach, facing a inshore reef that runs east all the way to Costa Azul. The midden contains both Saladoid and Ostionoid ceramic horizons, and is approximately 300 m

(984 ft) E-W by 200 m (656 ft) N-S The original site consisted of five mounds, one of these has been partly eroded by the sea Three of the mounds were excavated by Rainey (1940), who retrieved a relatively large number of complete or nearly complete ceramic vessels At the Shell or Ostiones level, both crude and red-slip ware were found, with the red paint generally applied in a rim band or in curvilinear patterns on the inside

Numerous burials were found at Embarcadero, "so close together that one skeleton could be distinguished only with difficulty from another" (Rainey, 1940 75) This prehistoric cemetery included burial urns for small children In Mound A, towards the center of the site and not the eroded one, several skeletons were found below the refuse, half submerged in water, a clear indication of a relative rise in sea level. Some of these burials were "fairly well preserved" (Rainey, 1940 78) Common shells at the site included *Strombus* sp, *Teltna* sp, and *Chama* sp Animal bones were abundant, including manatee, hutia, fish, and bird

Aguas Prietas Lagoon

Aguas Prietas Lagoon is located east of Bahía las Cabezas (also known as Ensenada Yegua) near Seven Seas Beach (North Coast-Fajardo) Surrounded in mangrove, the lagoon has a narrow outlet to the northwest, behind Cabeza Chiquita headland To the east, behind a secondary headland, the lagoon has nearly formed a second outlet A midden is located on the south side of this near-outlet

The edge of this Ostionoid midden is approximately 4 m (13 ft) from the tidal zone Surface collecting yielded the standard crude and smooth ceramic wares A dive inspection of Bahía las Cabezas was conducted, using

both scuba and snorkeling gear With the exception of one Ostionoid sherd in very shallow water, at the eastern end of the bay, no archaeological materials were found under water

Cabezas de San Juan

Cabezas de San Juan is a narrow peninsula that forms the northeastern tip of the island (East Coast-Fajardo) The site is located northeast of Laguna Grande, near the fishing village and marina of Las Croabas The site is an Ostionoid burial ground, situated in a small valley facing the nearby island of Icacos A long beachrock pavement runs along the beach. In it are the lithified remains of at least five burials aligned along the beach (Figures 10 and 11)

As the sand became beachrock, the skeletons were for the most part dismembered, but preserved in their original place In one case, the fetal position is clear All five bodies appear to have been accommodated inside large, thick walled, unpainted ceramic vessels Pottery shards from these vessels are embedded in the beachrock pavement Originally, two skulls were visible on the surface of the pavement, but were chiseled away by a pot hunter As a note on toponymy, these skulls may have been the "cabezas" or heads of San Juan, although the name may also have arisen from the shape of the peninsula itself Preliminary surface collecting by the author yielded two cassava griddles, one perforated rim sherd, and various crudeware and smoothware sherds A small midden is found adjacent to the burial ground The area of Cabezas de San Juan is now a restricted natural preserve under the Fideocomiso de Preservación de Puerto Rico

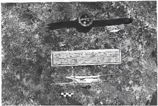


Figure 10. Lithified prehistoric burial 1, Cabezas de San Juan.

Ensenada Honda

This site is located on a small islet on Caño de los Indios Inlet Ensenada Honda Harbor (East Coast-Ceiba). Ensenada Honda and surrounding areas are within the U.S. Naval Station of Roosevelt Roads. The islet is located on the south side of the mouth of the inlet, between a

mangrove swamp and the sea. This is a ceramic midden containing primarily Elenoid pottery, with some Cuevas and Esperanza sherds (Rouse 1952b:548). Rouse's excavation at Ensenada Honda yielded numerous cassava griddle sherds, a clay figurine, clay disks, a bone pick, a bone spatula, shell celts and a chisel, a shell bead, a shell pendant, hammerstones, etc. The midden was composed of marine bivalves and univalves, as well as snails, and bones of manatee, hutia, bird, sea turtle, and fish (Rouse 1952b:550).

Figure 11. Lithified prehistoric burial 2. Cabezas de San Juan.

Playa Blanca

Playa Blanca is one of three middens on the main island of Caño de los Indios at Ensenada Honda (East Coast-Ceiba). The island is separated from the sea by a mangrove swamp. It is a small site, approximately 10 m (33 ft.) in diameter. Only one isolated pottery shard was found at the surface, otherwise, it appears to be a preceramic midden. Relatively few artifacts were located, including shell tips, a stone chip, blunted clam shells and coral fragments. The midden is composed of marine bivalves and univalves, snails, crab, fish, manatee, and hutia (Rouse 1952b: 550).

Petroglyphs-Caño de los Indios North

These petroglyphs are located on the north side of Caño de los Indios inlet, Ensenada Honda (E-Ceiba N.E.). First reported by Alphonse Pinart in the 1880's, the petroglyphs consist of two anthropomorphic figures and part of a third, at the edge of the water (Tronolone et al. 1984: 3-11). The petroglyphs are carved on large boulders at the edge of the mangrove swamp, across the inlet from the site of Ensenada Honda.

Petroglyphs-Caño de los Indios South

These petroglyphs are located just off the shore of a small island near Ensenada Honda site (East Coast-Ceiba). They are approximately 800 m (0.5 miles) south of the first set of petroglyphs. An anthropomorphic face with six lines radiating from the chin was reported by Rouse (1952b: 549).

More recently, a second human figure was discovered nearby, as reported by Woods (in Tronolone et al., 1984: 3-14).

Cayo Santiago

Cayo Santiago is a small island off Humacao Beach (East Coast-Humacao). A ceramic shell midden is located on the low, northern part of the island. The midden is 50 m (164 ft.) in diameter and 75 cm (2.5 ft.) deep. Ceramics are mostly Santa Elena and Esperanza (Rouse 1952: 551). The island has a maximum elevation of 34.9 m (114 ft.), and is separated from the parent island of Puerto Rico by a channel roughly 400 m (1312 ft.) wide and 1.5-2.4 m (5-8 ft.) deep. The bathymetry of the area clearly indicates that Cayo Santiago was connected to the parent island in prehistoric times, the rocky point of a now submerged coast. Nearby Humacao Beach is an area of severe erosion (Morelock 1978: 40). At present, Cayo Santiago is used by the School of Tropical Medicine of the University of Puerto Rico, as a laboratory for primate research.

Jobos

The site of Jobos consists of 5 middens 1.3 km (0.8 miles) inland from the Bay of Jobos (South Coast-Guayama). The middens are spaced an average of 100 m (328 ft.) over the coastal plain. One of the middens contains prehistoric ceramics. One brick and three Spanish pottery shards were also found. The rest of the middens appear to be preceramic. Rouse (1952b: 539) has written: "Jobos is of dubious significance. It is situated too far from the shore to be a place were shells were gathered." Yet, he adds

that "the shells are well bleached as in Indian sites, and the heap has an appearance of antiquity." A tentative preceramic origin was assigned by Rouse to some of the middens. Three decades later, Jobos remains a problematic site (Dávila 1985: 31).

Cayo Cofresí

Cayo Cofresí is a preceramic shell midden at Jobos Bay (South Coast Jobos). The site itself forms an islet at the south end of the Mar Negro (Black Sea) mangrove lagoon. The midden is roughly 50 X 40 m (164 X 131 ft.). Part of the shell midden is now submerged.

Cayo Cofresí was excavated in 1973-74 (Veloz et al. 1975), yielding hammerstones, blades and microblades, choppers, scrappers, grounded cone manos, conch picks, and a variety of shell tools. The people of Cayo Cofresí ate turtles (*Chelonia mydas*), fish, crab, bird, and hutia (*Plagiodontia*). The fish included barracuda (*Sphyraena*), ray (*Aetobatidae* ?), and jack (*Carangidae*). The most common shellfish at the site were *Arca* sp., *Cittarium pica*, *Strombus gigas*, and *Cassis tuberosa*. The remains of three new-born babies were also found, suggesting simple disposal without funerary rites of any sort (Veloz et al. 1975: 24).

Legend has it that the Puerto Rican pirate Roberto Cofresí buried a treasure here. This has led to considerable destruction of the midden by treasure hunters in search of imaginary gold.

Cayito

Punta Cayito is located at the west end of Santa Isabel Beach, near the Coamo River (South Coast-Santa Isabel). The large midden at Cayito is characterized by Boca Chica ceramics (Rainey 1940: 112), which are roughly contemporary with the late Ostionoid. Additionally, Elenoid, Ostionoid, Capá and Esperanza pottery sherds are present in lesser quantities.

Most of the site is now covered by houses. On the south side of the point, the sea has cut into the midden. Artifacts at the site included cassava griddles, a clay dish, stone cylinder, stone celt, bone disk, bone peg, blunted clam shells, coral fragments, etc. Foodstuffs included marine bibalves and univalves, bird, crab, fish, hutía, manatee, and sea turtle (Rouse 1952b: 532).

Bay of Montalva

The Bay of Montalva is located east of La Parguera, off the Fortuna salinas or salt pits (South Coast-Lajas). An Ostionoid ceramic midden has been reported for one of the twenty-plus mangrove islets in the bay (Mason 1941: 271). The midden is composed primarily of univalves, with small quantities of oysters, clams, mussels, and pecten bivalves. According to the topographic map at the State Historic Preservation Office in San Juan, the site is located on the largest of three islets off the old public school south of the salinas. Locals interviewed by the author call this islet Cayetero, but reported no knowledge of a shell midden there or in the two islets nearby. Snorkeling around Cayetero and then traversing it, the author was unable to locate the site. According to Mason (1941: 271), the islet is approximately

118 m (130 yards) long and completely covered with shell, and is probably one of the offshore, mangrove-free islets of the Bay

Papayes

Papayes is located between the Bay of Montalva and La Parguera (South Coast-Lajas) The site includes 18 middens on "slight rises of land at the edge of an extensive mud flat" (Rouse 1952b 540) No prehistoric ceramics were found, but an iron belt and one European pottery shard were found on the surface of a midden Presuming that these two items were intrusive, Rouse has suggested a possible preceramic origin for these middens Tools include stone chips, a stone slab, blunted clam shells, shell tips, and two coral fragments

Magueyes

Magueyes is a small oval shaped islet near the town of La Parguera (South Coast-Lajas) The Field Laboratory of the Institute of Marine Biology of the University of Puerto Rico is located there The islet is separated from Puerto Rico by a very shallow canal roughly 100 m (328 ft) wide The south and east coast of Magueyes are mangrove, as is most of the coast of La Parguera and the south coast in general The highest point on the island is 27 m above MSL

A shell midden is located on the northeast corner of the islet. The midden has very few potsherds, which may be classified as early Ostionoid Most artifacts are made of shell, including celts, cups, polished pendants, disks, and three-pointers (Cosmans 1965 20) Common univalves at the

site include *Strombus costatus* Gmelin, *Strombus gigas* Linné, *Strombus pugilis* L , *Chicoreous brevifrons* Lamarck and *Cassis tuberosa* L Common bibalves include *Anadara notabilis* Röding, *Chama macerophylla* G , *Chama sinuosa* Broderip, *Arca zebra* Swainson, and *Chione granulata* G It is worth noting that *Anadara notabilis* , while common at Magueyes, is now considered rare or absent in Puerto Rico (Coomans 1965 18)

Coroso

Coroso is a precaramic midden near the town of Boquerón (Southwest Coast-Cabo Rojo) Located 1 km (0 6 miles) north of Sucia Bay and 1 km from the west coast, the site is a single midden of both bivalve and univalve shellfish. The midden is 20 m (65 6 ft) in diameter and 25 cm (.8 ft) deep Artifacts include hammerstones, blades, a shell cup made of Strombus, shell points, and a coral fragment No water supply is available (Rouse 1956 379 Dávila 1985 28)

Boquerón

Boquerón is a large ceramic site near the bay of the same name (West Coast-Cabo Rojo) The site is some 200 m (656 ft) in diameter and 50 m (164 ft) from shore Rouse (1952 374-6) reports Ostiones and Cuevas wares, as well as clay griddles, a discoidal clay stamp, an anthropomorphic stone pendant a shell blade, a shell tip, etc An Ostionoid child's burial was excavated This was in very poor condition and had no associated artifacts

Ostiones

The site is located at the tip of Punta Ostiones (West Coast-Cabo Rojo). Excavated by Lothrop, de Hostos, Spinden, Montalvo, Rouse, and numerous pot hunters, the original midden had a diameter of 100 m (328 ft.) and consisted of six mounds, five of these forming a horseshoe (Ramey 1940: 117; Rouse 1952a: 395).

The site is situated on a low, sandy point between the ocean and a mangrove swamp. Excavations by Rouse and others yielded a wide assortment of pottery forms, including bowls, cassava griddles, cylindrical discoidal stamps, a spherical clay bead and a clay three-pointer or zemi. The site has also yielded stone celts and chisels, stone polishers, stone cylinders, shell-tip hammers, a shell disk, shell celts, etc. (Rouse 1952: 397).

Recent observations by the author revealed a curious geomorphological feature unreported by previous researchers. The south or seaward end of the site is beachrock, with numerous pottery sherds embedded in it. Yet, the actual shoreline is not there, but some 12 m (38 ft.) south of the beachrock "pavement". This suggests two shoreline movements since the time of prehistoric occupation. First, the sea advanced to the edge of the midden, where the beachrock pavement was formed, then the shore prograded, leaving the pavement inland. The implications of these observations are discussed in Chapter 5.

Cayo Ratones

Cayo Ratones is a small islet located off Joyuda (East Coast-Cabo Rojo). Also called Pinos and Pinero in historic times (Cardona 1985: 85),

Cayo Ratones is roughly 122 m (400 ft) E W by 82 m (270 ft) N-S The islet is presently at a distance of 427 m (1400 ft) from the parent island of Puerto Rico, separated by a protected channel with a maximum depth of 4 8 m (16 ft)

The west or offshore side of the islet is protected by remnants of beachrock. The center has sufficient soil to support a small wooded area of pines and other coastal vegetation. The rest of the islet is sand. Immediately south of Cayo Ratones, at a depth of 2 m (6 5 ft) and shallower, Ostionoid pottery shards may be seen on the sandy bottom The ceramic material is uncovered on a seasonal basis, which makes it difficult to estimate the extent of the deposit, but apparently covers at least 20 m (66 ft) in circumference

<u>Joyuda</u>

This Ostionoid site is just off the town of Joyuda, (West Coast Cabo Rojo) In 1915, Lothrop excavated at Joyuda, noting that "the sea is cutting into it and many objects have been found on the beach A few years ago several skeletons were dug up which were reburied in the Cabo Rojo cemetery" (in Rouse 1952a 398)

Joyuda was also excavated by de Booy in 1916 and de Hostos in 1917 Based on his own surface collecting and on examination of materials from previous excavations, Rouse (1952a. 398) reports that most ceramics at Joyuda are Ostionoid, with some representation of Cepá sherds and a few Elenoid shards as well The material included cassava griddles, discoidal clay stamps, a cylindrical clay bead stone pestles, a stone adze and celts a cylindrical stone bead, an anthropomorphic stone pendant, shell celts, a shell

bead, etc. Based on ceramic analysis, Rouse (1952a 395) has suggested that Joyuda may be somewhat later than the type site of Ostiones to the south.

Petroglyphs Punta Ensenada

These petroglyphs were located at the tidal zone in Barrio Ensenada, (West Coast Rincón). Carved in beachrock, the petroglyphs appear to be of Ceramic Age origin, although their exact cultural affiliation is not entirely clear. At nearby sites, there is evidence of Ceramic Age occupation from early Saladoid through Ostionoid and Chicoid stages (Rodriguez 1985 4). Moreover, at the site of Ensenada, early 16th century Spanish artifacts have been found, including coins, indicating aboriginal activity into historic times (Cardona 1986 13).

Mar Chiquita

Mar Chiquita is a lunate resonating basin at Manatí (North Coast Manatí). An Ostionoid midden is located approximately 600 m (1970 ft.) east of the basin, directly south of a small islet. This islet is a remnant of the same eolianite ridge that forms the Mar Chiquita basin. The midden is partly exposed at the beach scarp, and at the furrows of rain run-off. Numerous pottery shards are embedded in the long, narrow beachrock pavement fronting the beach.

Tortuguero

This Ostionoid site is located NW of Tortuguero Lagoon, between Mar Chiquita and Puerto del Tortuguero (North Coast Manatí). A narrow beach fronts short, limestone cliffs with minor karst formations. It is clear that this site had a number of seaside caverns at the time of prehistoric occupation. A preliminary inspection suggests that some of these caverns were occupied by the aboriginal population. Eventually, the caverns collapsed due to marine erosion. Abundant pottery sherds are visible at the base of the cliffs.

Maisabel

Maisabel is one of various prehistoric sites between the eolianite ridge of Punta Puerto Nuevo and the wetlands of Boca del Cibuco (North Coast Vega Baja). Excavations at Maisabel have been recently undertaken by the Centro de Investigaciones Indígenas de Puerto Rico (Siegel 1986). As is usually the case, the pot hunters have also done a considerable amount of digging at this important site.

The site of Maisabel is cut from the beach by a paved road. Pottery sherds are visible by the roots of trees along the road. On the beach, the beachrock pavement is decorated with a variety of petroglyphs. Seven petroglyphs were identified by the author; presumably, others may be found beneath the sand. The exposed petroglyphs are flooded by the sea at high tide.

Due to the friable nature of beachrock, and the relatively smooth cut of the petroglyphs, it is likely that the prehistoric artist worked during the

incipient stages of the pavement At this stage, beachrock has the consistency of semi dry cement, and the artist s technique may be an intermediate stage between pictograph sketching and petroglyph carving

A dive search was conducted in the semi protected embayment between the beachrock coast of Maisabel and the eolianite ridge of Punta Puerto Nuevo Only two sherds were found one historic, the other a monochrome, Ostionoid-like sherd This simple dive inspection revealed that the embayment is not as suitable for canoes as a surface view might suggest Boulders rise close to the surface, and in rough weather the waves explode against the eolianite ridge If canoes were used here, they were small It is far more likely that the prehistoric inhabitants had access to the sea by Punta Garza and the mouth of the Cibuco River to the east Once they knew the coast, the prehistoric navigators had no difficulty launching or landing a canoe at the Boca del Cibuco

Playa Cerro Gordo

Playa Cerro Gordo is located east of the Cibuco River (North Coast Vega Baja) A large number of Ostionoid pottery sherds are embedded in beachrock for more than 500 m (1640 ft) along the beach The midden itself is located in private land near the border of the Vega Baja Vega Alta Municipios No ceramics were found underwater

Punta Mameyes

Punta Mameyes is located north of Dorado Airport (North Coast Dorado). The site reaches to the tip of Punta Mameyes, and is partly eroded, to the south, it is partly covered by landfill of a nearby hotel. A narrow beachrock pavement runs along the point, with Ostionoid pottery and shells embedded in it. Isolated pottery shards may be found under water.

Punta Corozo

Punta Corozo is an eolianite point that protects the mouth of the Cocal River (North Coast Toa Baja). The site is located on both sides of the mouth of the river, with most of the refuse on the west bank, near the tip of Punta Corozo. The Cocal River is a secondary outlet of the larger Plata River to the west. Immediately south of the site, the Cocal widens as it drains a relatively large swampland. This site is an Ostionoid midden extending at least 40 by 40 m (131 ft.). The eroded walls of the midden are clearly visible on the west bank of the Cocal River. A dive search was conducted off the site. Due to the presence of the river, underwater visibility tends to be poor, but the high tide allowed us sufficient visibility to verify that the midden stops at the tidal zone.

Historic Sites and Documents

> Some scientists today refuse to believe that there are any sunken cities simply because to them a sunken city is by definition an irrational concept. This is just as shortsighted as believing in Lemuria.
>
> Nicholas C. Flemming (1972: 25)

Non te cases cun ferreiro
Que é mui malo de lavare
Cásate cum mariñeiro,
que ven lavado de mare!
Galician Folk Song (in Cunqueiro 1983: 28)

Historic evidence of coastal change includes archaeological sites as well as cartographic, documentary, and photographic data. In theory modern coastal change is intrinsically historic, and need not be placed in a separate information domain. Whether a coastal structure is Puerto Rican 1925 or Colonial Spanish 1625, in either case it pertains to a literate (historic) culture and as such may be dated with great precision.

This section examines diverse historic markers of coastal change in Puerto Rico (Figure 12). These sites provide further evidence of coastal

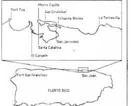


Figure 12 Location of historic sites used for the study

change up to the present adding support to the Model of Caribbean Submergence presented in Chapter 5. Moreover, historic sites are important in their own right, and therefore should be included here, in order to promote awareness of sea levels in historical archaeology (Table 3). We shall now look at selected historic evidence of coastal change for the main island of Puerto Rico.

Fort Toa

Toa Bay is a large, lunate embayment west of San Juan Harbor. When the city was founded, the Spanish authorities at San Juan believed that this bay was completely secluded from the sea by a chain of reefs. In 1647, however, marine surveyors found an entry large enough for warships to get in, an obvious threat to the defense of San Juan (Junta de Guerra 1662, Lopez 1975: 213).

The gap in the reef was too wide and deep to be closed with rubble, compelling the governor to build a fort (Novoa 1660). Started in 1662 and completed in 1664, Fort Toa was built on an islet "*en medio de la mar*" -- in the middle of the sea -- near Punta Salinas. It was a square structure made of cutstone, large enough to hold 200 soldiers, and provided with six iron cannon and a bronze piece (Perez de Guzmán 1664a). A quay, 2.5 m (8.25 ft.) long, was built of stones dumped within timberwork. Toa Bay is depicted in a 1660 map produced by Capt. Vicente Durán (Figure 13). This rather impressionistic map was made two years before the construction of the fort was initiated, but from the archival data it is clear that the fort was built at the "Toa Islets" depicted by the letter "H" in Durán's map.

TABLE 3

Description of Historic Sites Used in the Study

Site	Coast	Sea Level History	Date
Fort Tos	N	Cutstone fort built on islet Presumably submerged	1664
San Juan de la Cruz El Cañuelo	N	Masonry fort on islet Base under MSL in the 1930's Now tied to PR through land fill	1660's
La Fortaleza- Santa Catalina	N	Massive seawall undermined by sea in the 1750's Modern land fills and repair	1634
Morro Castle	N	Massive seawall undermined by the sea throughout history Modern land fill and breakwater	1589
San Cristóbal	N	Massive seawall. Extensive damage reported in 1651 and 1769 Profile of 1769 show lower MSL	1625
San Jerónimo	N	Cutstone and brick fort Base is 70 cm under water	1587
Eollantie Blocks	N	Placed by military engrs. to block entry to lagoon Sea level nips under MSL	1797-99
La Torrecilla	N	Fortified watchtower Lost, presumably submerged	1608-11
Fort San Francisco	W	Masonry fort hit by earthquake and tidal wave in 1918 Outside wall within tidal range	late 18th century

In 1797, the year of the British invasion under General Ralph Abercromby, the Spanish built yet another fort, this one on the main island east of Punta Salinas, since then known as Isla Batería (Cardona 1985 17). Made of masonry, its foundations were 22.8 m (75 ft.) above sea level (MSL: 1797). The ruins of this small fort are still standing, and should not be confused with the elder Toa Fort. In a letter to the king of Spain, Gov. Pérez de Guzmán (1664a) indicated that two bridges were used to transport the construction materials to the islet, as the surrounding water was too shallow and rocky to allow cargo boats. Both bridges had a span of 457 m (1500 ft.), meaning that the fort was roughly 914 m (3000 ft.) from shore.

Evidently, the ruins of Fort Toa are beyond Isla Batería, which is less than 100 m from Punta Salinas. A 1842 nautical chart of Puerto Rico (General Library, University of Puerto Rico, Río Piedras Campus), clearly depicts the two reefs between Punta Salinas and Cabras Island. Presumably, the submerged remains of Fort Toa are to be found in the shallows of the western reef, off Punta Salinas.

Currently under the jurisdiction of the U.S. Armed Forces, Punta Salinas is a tombolo with signs of considerable erosion. Nearby Levittown Beach is also being eroded. The problem appears to be largely due to the Isla de Cabras causeway, at the west end of San Juan Harbor. Built during World War II (Cardona 1985: 20), this causeway has radically changed the current and wave patterns in the Toa lunate embayment, resulting in accelerated erosion (Morelock 1978: 26). An additional factor to be considered is the redirection of the Toa River in late historic times, which now drains east of the embayment, greatly reducing the sediment supply to Toa Bay.

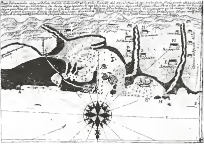


Figure 13. Plan of San Juan, depicting La Torrecilla (A), El Boquerón (B), Morro Castle (C), Toa Bay (G), and Toa Isleta (H). By Capt. Vicente Durán. 1660 (Archivo General de Indias, Mapas y Planos, SD 60)

San Juan de la Cruz - El Cañuelo

San Juan de la Cruz, commonly known as El Canuelo, is a small fort built across the harbor from Morro Castle. Originally located in a small islet behind Cabras Island. El Cañuelo was built of wood in 1610 or thereabouts, burned by the Dutch in 1625, and rebuilt in masonry in the 1660s. Both the islet and the fort are clearly depicted in Luis Venegas de Osorio's 1678 plan of San Juan Harbor (Figure 14). In a letter to the king of Spain, Gov. de Medina (1695) indicated that one of the walls of El Canuelo had been badly damaged by the continuous attack of the sea. No mention is

Figure 14. Plan of San Juan (detail), depicting Fort El Canuelo on a small islet. By Engr. Luis Venegas Osorio, 1678 (Archivo General de Indias, Mapas y Planos SD 74)

made of hurricanes or storms Gov de Medina indicated that his predecessor, Gov Gaspar de Arredondo, built a stone groin around El Canuelo, as protection against the sea's attack on the fort It is clear that the small islet of El Cañuelo was losing ground at a fairly rapid rate in the late 17th century

Originally, El Cañuelo islet was 457 m (1500 ft) from shore, as indicated by the span of the wooden bridge built to transport the construction materials for the fort (Perez de Guzmán 1664) This is is confirmed by various maps of San Juan produced in the 18th, 19th and 20th centuries The most recent map in which the islet of El Canuelo is shown was produced in 1943, by Sergeant Charles Lipinski (Archivo General de Puerto Rico, Colecciones Particulares-Sueltas Paquete 7) That same year or soon after, the U S Army Corps of Engineers filled the shallows surrounding El Cañuelo, in order to facilitate access to military installations at Cabras Island (Cardona 1985 18)

In a plan and two profiles of El Canuelo produced in 1938 (Archivo General de Puerto Rico, Colecciones Particulares-Sueltas Paquete 7), Capt Henry B Margeson indicated that some of the walls are cracked, which he attributes to "earthquakes or the settling of the foundations" And he adds that "the waves have eaten into the base of the fort around its entire perimeter" The profiles clearly indicate that, by 1938, the foundations of El Cañuelo were under water

La Fortaleza Santa Catalina

Completed in 1540, La Fortaleza is an early stronghold overlooking the inside of San Juan Harbor In 1634 or soon after, Engr

Juan Bautista Antonelli built the massive walls in front of La Fortaleza, which came to be known as Santa Catalina. This was part of an ambitious undertaking to circumscribe the city of San Juan with fortified walls and bastions, a project that was finished by 1638 (Vila Vilar 1974 178-181). In a 1752 letter to the king of Spain, Gov Calderón indicated that the walls at Santa Catalina had been undermined by the sea, and were in dire need of repairs (Calderón 1752)

Morro Castle

The fortification of San Juan's Morro or headland began in 1540 with a round tower overlooking the narrow entrance to the harbor (Ribes Tovar 1973 77) Construction continued until the late 18th century The oldest walls date from 1589, while most of the superstructure as we see it now dates from the late 18th century Fear of attack as well as actual invasions persuaded most of Puerto Rico's early governors to add new elements or repairs to the stronghold San Juan was attacked in 1595 by Sir Francis Drake in 1597 by the Earl of Cumberland, in 1625 by the Dutch under Boudewyn Hendrickszoon, and in 1797 by Gen Ralph Abercromby In 1898, the first shot of the Spanish-American War was fired from Morro Castle Wisely, the U S invasion troops were landed at the much weaker port of Guánica, on the south coast (Rivero 1973)

The sea has been a less conspicuous but constant invader against Morro Castle The fortress lies atop a large headland of eolianite origin, of which four separate generations of cemented dunes have been identified by Kaye (1959b 128) Throughout its history, there are numerous instances in which El Morro's seawalls had to be repaired against the attack of

the sea (Lopez Canto 1975 211) In recent years, from 1977 to 1988, some $33 million have been spent on repairs at El Morro For the most part damages have been due to wave action against the walls The problem appears to have increased through the centuries, prompting the construction of a 228 m-long (750 ft.) breakwater to protect the ancient walls against northerly seas (Olsen 1988 3) This breakwater is currently under construction

San Cristóbal

In 1634, San Cristóbal was a small installation at the northeastern end of the San Juan headland, overlooking both the north coast and the city Larger than El Morro San Cristóbal was completed by 1783, and played a prominent role in the defense of the city against the Dutch invasion of 1797 In 1651, a report on Puerto Rico's defenses indicated that the seawall at San Cristóbal, built in 1625 or thereabouts, was in need of repairs (Lelez Canto 1975 211)

In 1769, San Cristóbal's seawalls were in need of repairs once again This time, the governor's report was accompanied with three profiles by engineers Juan Francisco Mestre and Tomás O Daly (Figure 15) Two of these profiles provide mean sea level (MSL-1769) Preliminary observations suggest a 25 cm increase in sea level in the last 220 years

San Jerónimo

Fort San Jerónimo is located on the west side of El Boquerón which is the entrance to Condado Lagoon This body of water separates San Juan

islet from the Santurce-Cangrejos islet Today, visitor and resident alike are seldom aware of these islets, camouflaged into a single land mass by bridges land fills and urban development

Fort San Jerónimo played a key role in the defense against the British invasion of 1797 Although the fort itself dates from the 17th century, its foundations were laid in 1587 The original structure consisted of a platform with two iron cannon, but large enough to accommodate six pieces (Menendez de Valdez 1587) Both the foundations and the seawall consist of eolianite cutstone, cemented with mortar and reinforced with rectangular bricks

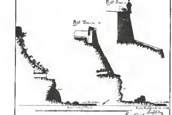


Figure 15 Profiles of Fort San Cristobal, with 1769 sea level. By Engrs Juan Francisco Mestre and Tomás O'Daly, 1769 (Archivo General de Indias, Mapas y Planos, SD 367)

Diving around the perimeter of the fort, the author estimated the foundations to be 70 m (229 ft.) under water. Although the techniques for underwater construction are known since Roman times, Spanish documents give no indication that this was the case at San Jerónimo. Off the NE corner of the fort, a brick rubble zone was discovered at a depth of 2.4 m (8 ft.), evidence that the superstructure or the wall itself has been damaged by the sea in historic times. The area's exposure to storm waves is also indicated by a small, fishing pier connected to the south or inshore side of the fort. Solidly built like a seawall, the pier was frequently used by fishermen less than ten years ago. On occasion, small sharks were caught from it. Today, the partly destroyed pier is some 12 cm (5 in.) under water. An isolated, prehistoric pottery shard (Ostionoid) was found by diving in the middle of the channel. Presumably, this shard travelled from an intertidal or submerged prehistoric site in the Condado area.

Eolianite Blocks - Condado Lagoon

On the east side of El Boquerón, opposite Fort San Jerónimo, the channel is partly blocked by large eolianite blocks. According to Angel Rivero, a soldier-historian who served as Commanding Officer of Fort San Cristóbal during the Spanish American War, the eolianite blocks were placed there in 1797, to partly close El Boquerón in anticipation of the British invasion under Gen. Abercromby (Rivero 1973: 65).

In 1789, two years after the British siege, a plan to block the entrance to El Boquerón was proposed (Vertiz 1799). Unless this meant to further close the channel, the blocks were placed in 1799 rather than in 1797.

Either way, it is clear that the blocks were blasted from the nearby eolianite formation in El Condado, and placed in the channel in the late 1790s.

In a survey of the sea-level notches or nips that have formed on the blocks, Kaye (1959b: 119) concluded that sea level (MSL 1959) has remained stable since 1737. However, he qualifies his "present sea level" as "plus or minus two feet" (Kaye 1959b: 50). From a geological perspective, a 0.6 m (2 ft.) rise in sea level might be considered negligible, but to the archaeologist it may have tremendous significance. Unlike Kaye, the author inspected the walls by scuba diving, observing sea level nips at least 16 cm (0.6 ft.) under the present MSL. However, underwater observations suggest that some of the blocks may have moved in the last two centuries, due to the undermining of sand beneath the blocks. Additionally, this particular area tends to get fairly rough, which makes it difficult for the scuba diver or snorkeler to conduct accurate observations except in the best weather.

La Torrecilla

La Torrecilla was a fortified watchtower at Boca de Cangrejos, east of San Juan. The purpose of this military installation was to defend the area's plantations against waterborne raids by Carib Indians during the late 16th and early 17th centuries.

In a letter to the king of Spain, plantation owner Matías Piñero (1604) requested "*cinco o seis hombres blancos de confianza*" – five or six white men of trust – to protect the planters against Carib attacks. In 1605, the Crown approved Piñero's petition. Six years later, the Oficiales Reales or Royal Officers of San Juan (1611) prepared a report on the deeds of Puerto Rico's Gov. Gabriel Rojas Páramo, including the construction of La

Torrecilla at Cangrejos Gov Páramo served from 1608 to 1615 (Vila Vilar 1974 85), which indicates that La Torrecilla was built sometime between 1608 and 1611

In Capt Vicente Durán's 1660 map (Figure 13), La Torrecilla is depicted under the letter "A" at the extreme left. The legend indicates that the watchtower had "*puerto para barcos* " - a seaside pier In a 1937 map of Puerto Rico at Seville's Archivo General de Indias (Mapas y Planos, Santo Domingo 524), the point adjacent to Boca de Cangrejos is called Punta de la Torrecilla In 1775, Miyares (1954) reports that La Torrecilla is no longer standing The watchtower's foundations have never been found Presumably, they are under water Today, Boca de Cangrejos and nearby Maldonado Beach are areas of severe erosion (Mareleck 1978 25) An unusually long beachrock pavement runs from Cangrejos into the sea for 400 m (1 300 ft) To Kaye (1959b 117), this pavement indicates "a profound change in shore outline with the removal of at least 1,200 feet of shore "

The first bridge at Boca de Cangrejos was built of wood in 1660, as reported by Gov Joseph de Novoa y Moscoso (1660) Four years later, the new governor reported that the bridge was destroyed by a storm, and rebuilt that same year in wood (de Velasco 1664) In September of the present year of 1989, surge from Hurricane Hugo caused sufficient erosion to weaken the foundations of the cement bridge at Boca de Cangrejos, now to be replaced by a metal one The historic data clearly indicates the unstable nature of Cangrejos further substantiating the hypothesis that La Torrecilla's foundations are now submerged, or at best buried under sand at the intertidal zone

Fort San Francisco

The forsaken structure of Fort San Francisco is located behind the public school at Sector Tamarindo, Aguadilla, on the west coast. This small installation was built in the late 18th century, to provide protection to the exposed bay area, once a prominent harbor. During a marine survey of adjacent Tamarindo Reef conducted by maritime historian Walter Cardona and the author (Vega 1987), it was noticed that the sea now washes against the outside wall of the fort, clearly indicating a change in relative sea level.

Tamarindo and other sectors of Aguadilla subsided due to the earthquake of 1918, followed by a tsunami or tidal wave which wiped out the wooden houses adjacent to the fort. One witness wrote that, a few minutes after the earthquake, "a horrendous sea wave invaded the beach, tore off the house, and carried it to the depths of the sea" (in Benítez 1920). The late 17th century also appears to have been a time of tectonic adjustments in the Mona Passage area, with "great earthquakes" reported for the west coast (Cabildo de San Germán 1680) followed by "constant earthquakes" eight years later (Cabildo de San Germán 1688).

CHAPTER 5
A MODEL OF CARIBBEAN SUBMERGENCE

Within the last 15,000 years, the dominant pattern of Caribbean coastal geomorphology has been one of submergence In spite of geologically recent tectonic uplift and prograded coasts in the Caribbean Archipelago, the overall process has been a flooding of coastal zones Significant variations are recognized in the sea level history of Caribbean islands, particularly between the continental and the oceanic islands (as discussed in Chapter 3) Nonetheless, it is clear that the submerged shelves of all island groups share sufficient oceanographic, geomorphological paleo ecological and prehistoric cultural traits to warrant a regional geoarchaeological model of Caribbean shoreline migration

The Model of Caribbean Submergence (MCS) is a predictive as well as an interpretive model for the archaeological reconstruction of sea levels and coastal change In its widest scope, the model is intended for the entire Caribbean archipelago Its aim is not simply to predict high-probability areas for locating sunken sites, but more importantly, to present a systemic approach to coastal geoarchaeology in general In this last regard, the model is by no means intended exclusively for diving archaeologists

The central premises of MCS are as follows 1) that coasts are transient boundaries that fluctuate across continental or island shelves in response to sea land level changes, and 2) that coasts were the habitat of many, if not most, Caribbean prehistoric peoples Considering that the sea has risen an estimated 85 to 135 m (278-443 ft) in the last 15,000 years, it follows that vast tracts of the Caribbean prehistoric landscape are now under water, most likely including the earliest archaeological record for the region

The model follows a logical progression from the comparative study of intertidal and shallow-water sites, to predicting the location of deep-water sites. Beyond method and theory per se, this chapter also explores diverse strategies for promoting archaeological awareness of sea levels and submerged land sites in the Caribbean

Conceptual Framework

> I seem to have been only like a boy playing on the seashore, and diverting myself now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me
>
> Isaac Newton 1642-1727 (in Meredith 1977 2)

> On all these shores there are echoes of past and future: of the flow of time, obliterating yet containing all that has gone before
>
> Rachel Carson (1955 11)

Models provide both tools and perspectives with which to examine archaeological sites (Butzer 1982 211) Ideally, an archaeological model should be firmly based on field data, but at the same time transcend its empirical foundations in order to generalize beyond the spatial and temporal constraints of the observed sites

The empirical foundations of MCS have been presented in previous chapters These include general Holocene sea level changes (Chapter 2), general Caribbean archaeology and ecology (Chapter 3), and the author's coastal and marine surveys in Puerto Rico (Chapter 4) Inevitably, modelling implies chosing certain traits and theoretical problems and underplaying others This first version of MCS is particularly concerned with settlement patterns, shoreline migration, submerged site prediction, and modification of sites These are the primary areas that need to be researched in order to have a solid grasp on the problem Prior to presenting the results of the comparative study, it is essential to review the fundamental concepts behind it

Site Matrix and Eroded Materials

In high energy coasts, it is possible for artifacts to be transported offshore by rip currents, or down the coast by longshore currents In some cases, eroded materials may create the impression of intertidal or submerged sites

Of the thirty-six archaeological sites included in this study, only one could not be properly identified in terms of site matrix The site in question is Balneario Isla Verde, which appears to be either buried under pavement or eroded, with only sparse pottery shards visible at the intertidal zone The presence of these Ostionoid sherds on the beach indicates that shoreline migration has taken place, but not much else can be said about this particular site Was it a small site in the immediate area of the observed pottery shards, or a larger site further up the coast, towards Boca de Cangrejos?

Sea Level, Shoreline Migration, and Erosion

The Model of Caribbean Submergence makes a fundamental distinction between sea level change and shoreline migration. Sea level change is an expression of vertical (up-or-down) movement of the sea in relation to the coast, whereas shoreline migration is an expression of horizontal (prograding or retreating) movement of the shore. In areas of severe erosion, shoreline migration may occur without a rising sea level just as a rising sea level may result in little immediate shoreline migration on a cliffed coast. On low-lying coasts, the correlation of sea level to shoreline migration may vary from 1:100 to 1:1000. In other words, a rise in sea level of 3 m (1 foot) may drive the shoreline from 30 to 300 m (100 to 1000 ft.) inland (Eckholm 1986).

From a geoarchaeological perspective, the Puerto Rico data chosen for the study exhibits an interesting division between historic and prehistoric sites as sea level markers. While prehistoric sites are essentially ground-level middens or beachrock petroglyphs suitable for measuring shoreline migration, historic structures are "standing yardsticks" suitable for measuring sea level. The highly resistant nature of these Spanish forts is due to two factors: 1) the massive walls made to withstand cannonballs, and 2) the fact that most of them were built atop eolianite.

Beach erosion is the single most important factor in the destruction of intertidal archaeological sites. This type of erosion is largely the product of longshore currents, for the most part generated by waves striking the coast at an angle. Waves in turn are controlled by four primary variables: 1) wind direction, 2) wind duration, 3) wind velocity, and 4) fetch, i.e., the distance

traversed by waves without obstruction In open coasts, fetch is measured in hundreds or thousands of nautical miles, allowing the wind-generated waves to evolve into full seas For instance, a 50 knot (mph) whole gale requires 2630 km (1420 nautical miles) to produce a fully developed sea with waves averaging 14 6 m (48 ft) in height, and big waves up to 30 m (99 ft) and possibly higher (Bascom 1964 53)

Waves break when the water depth is roughly 1 3 their height, often reorganizing into smaller waves which will break in shallower water and so on until reaching a coast, offshore bank or reef Finally, although waves can direct enormous amounts of energy against a coast, at a depth of half the wave length (horizontal distance between two crests), their energy is reduced to 1/23 of the surface strength (Guilcher 1964 19) For submerged land sites, this implies that the greatest exposure to direct wave energy occurs during transgression, in exposed or partly exposed coasts

Seaside Settlement Patterns

Throughout history, coastal dwellers have built their homes as close to the edge of the sea as possible This phenomenon is so prevalent and universal, that the author is tempted to present it as a cultural law From fishing villages to slum dwellers, from mansions to resorts to middle-class homes, people will build as close to the water as possible Neither storms hurricanes, erosion, or tidal waves will change their minds The destruction of a Port Royal, Helike, or Pozzuoli always yields a moral lesson — seldom a geological one Even today, with the warning of geologists against a rising sea level due to the Greenhouse Effect, people refuse to give up the seaside strip

Of course there is no intention here of suggesting that all cultures at all times will chose the coast over the hinterland Obviously, there are numerous instances in which people will chose to live inland for direct access to fertile land, as well as for administrative, marketing, and traffic advantages, as explained by central-place theory (Butzer 1982 219)

The argument here is simply that, when people decide to live by the sea, they will be inclined to build as close to the water as possible Slumdwellers may do so because of land shortage Fishermen may do so in order to minimize the distance from boat to house There may be fish or meat or trade items to carry, boats to build and watch, perhaps enemy sails to watch, or merchant ships to be raided on the high seas In some instances, particularly among affluent sub-cultures, people may live by the sea for aesthetic reasons – simply to feel the breeze, watch the sea, and have quick access to the water

By combining this anthropological concept with the geomorphologist's beach profile, a specific area in the coastal zone is hereby established. This area is immediately behind the backshore, which extends from the upper limit of wave swash to the starting point of vegetation, a sand dune, or a sea cliff (Komar 1976 12)

At a global scale, the concept has three exceptions First are stilt houses, which may be built along periodically flooded beaches, and therefore within the backshore This is particularly a lakeside or river phenomenon, such as the Neolithic lake sites in Switzerland and Italy (Ruoff 1972, 1980) A second exception are artificial islands which are still being built by the Cuna Indians of Panamá and the Marsh Arabs of Iraq Archaeologically, the best known artificial islands are the crannogs of Scotland and Ireland These consist of submerged boulder mounds laid in

place by timberwork, again mostly a phenomenon of inland waters (Morrison 1980). Finally, a third exception are coastal caves, which people may occupy rather than build huts on the nearby edge of the backshore.

Estimated Shoreline Migration

Estimated Shoreline Migration (ESM) equals the estimated distance that a given shoreline has either prograded or retreated, as measured from a known archaeological site (Figure 16). This is done by mapping the site's position within the area's beach profile. Based on the principle of seaside settlement patterns discussed above, ESM can be used as a fairly acurate measurement of shoreline migration. By correlating the location, age, and ESM of diverse archaeological sites, it is possible to reconstruct the relative sea level history of particular coasts and islands.

Eventually, once sufficient littoral sites are known--meaning "littoral" in the wider geological sense, which includes the coast as well as the submerged portions of continental and island shelves--it will be possible to identify the position of paleoshores both above and below sea level, and to predict the location of submerged land sites.

Littoral Sites: Spatial Integration

> Whatever wisdom may be,
> it is far off and most profound
> who can discover it?
> The Bible, Ecclesiastes 7:24

> Sun splits the sea
> in two --
> one half's already bottled
> Shinkichi Takahashi (1981:140)

Marine transgression is a filter through which coastal sites may be modified but not necessarily destroyed. Contrary to the traditional view, there is growing evidence that land sites may survive transgression even in high energy coasts. This seemingly paradoxical situation is due to the fact that most coasts, even high energy ones, contain sheltered areas (Flemming 1983: 164). Seen through a LANDSAT photograph or small scale map (1:240,000+), the north shore of Puerto Rico appears as an exposed coast, which it certainly is in an overall sense. Yet, upon closer look (1:10,000 to ground truth), it becomes evident that even the rugged north coast has protected or semi protected zones behind headlands, islets, or reefs. These sheltered spots were commonly favored by prehistoric peoples (Masters and Flemming 1983).

Coastal Sites and Their Environments

Based on the comparative analysis of the prehistoric sites presented in Chapter 4, a number of significant patterns were recognized. Twenty-seven out of a total of twenty nine sites were located in protected or semi protected coasts, including nine out of eleven sites on the north coast.

The two submerged sites of Isla Verde and Cayo Ratones are both located on the inshore side of sandy islets, off the north and west coast respectively. These islets are protected by either beachrock (Isla Verde) or eolianite (Cayo Ratones), affording a barrier to both waves and ocean currents. It was interesting and rather surprising to notice that all six sites on islets are located off the east or south coasts, in areas where Puerto Rico's insular shelf exceeds 10 k (6.2 miles). Without exception, these islets

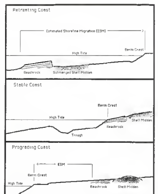


Figure 16 Geoarchaeological beach profiles of retreating, stable, and prograding coasts

are separated from the main island by shallow water, and undoubtedly were tied to Puerto Rico at the time of prehistoric occupation

Another surprising correlation has been noticed for the west coast While the Ostionoid site of Joyuda is intertidal, and the Ostionoid site of Caye Retones is submerged in shallow water, the contemporaneous site of Punta Ostiones is some 10 m inland As evidenced from the inland beachrock pavement, it is clear that sometime between prehistoric occupation and modern times, the coast has prograded at least 10 meters Moving further south, the Ostionoid site of Boquerón is 50 m inland On the south side of Boquerón Bay, the coast has formed an area of salinas or salt pits, as well as the large Boquerón Lagoon Finally, at Cabo Rojo, at the SW tip of the island, the preceramic midden of Coroso is 1 km from shore

Rouse (1952a 379) has written of Coroso "Since there is no water supply in the vicinity, the Indians themselves must have relied on rainfall, unless they carried water from a distance " Rouse adds that the site is not particularly suitable for shell gathering, as it is "not directly on the shore, where one would expect it to be" (Rouse 1952 381) Yet, shell was the staple and almost exclusive diet at Coroso, as no animal or fish bones have been found at the midden

Rouse's interpretation is an excellent example of the traditional approach in Caribbean archaeology, which implicitly assumes a stable prehistoric topography From a geoarchaeological perspective, it is clear that the southwest corner of Puerto Rico has been uplifted. This has resulted in significant alterations on the topography as well as the hydrology, and presumably the cultural ecology of the Cabo Rojo area As the SW coast was uplifted, the stream that once ran within a short walking

distance of Coroso dried up, and the shoreline pregraded, resulting in an inland site

The Coroso Controversy, A Geoarchaeological Perspective

Rouse's excavations at Coroso were the first evidence in favor of a preceramic horizon in Puerto Rico However, due to its location so far from shore, combined with its rather small size (20 m (66 ft.) in diameter, the archaeological community has been skeptical about a preceramic "Coroso culture" (Dávila 1985 28, 33) Excavating at Coroso in the late 1930's, Rouse carefully weighed the possibilities of this being a camp of ceramic Indians or even historic peoples Yet, in spite of an informal report of isolated surface potsherds, Rouse found neither historic nor prehistoric ceramic artifacts at the site (Rouse 1952 379) In a cultural chronology of the Greater Antilles published in the early fifties, Rouse (1951 251) included a preceramic Coroso horizon for Puerto Rico, contemporaneous with the preceramic Krum Bay Site in the Virgin Islands A few years later, the preceramic site of Cueva María de la Cruz was reported for Puerto Rico's north coast (Alegría et al 1955) As previously described, this is a cave site with a preceramic level beneath an Igneri-Cuevas ceramic level Excavations at this site proved that Rouse was correct about a preceramic horizon in Puerto Rico Yet, the Coroso site was virtually forsaken, excluded from Rouse's later chronologies of the Greater Antilles (Cruxent and Rouse 1969, Rouse 1964 503 Fig 5, Rouse and Allaire 1978 466, Fig 13 8) Following the non-controversial, preceramic discoveries at María de la Cruz, Coroso's preceramic west side story was relegated to a minor plane

But Rouse was right in the first place Coroso is the midden of preceramic coastal dwellers, its antiquity is proven by 1 km of shoreline migration [Coroso ESM ~ +1 km]. To illustrate the correlation between the antiquity of Coroso and shoreline migration, consider the ceramic site at Boquerón, where the coast has prograded some fifty meters [Boquerón ESM ~ +50 m] In comparison, shoreline migration at Coroso depicts a 2000% increase over Boquerón, far too much to be explained by synchronic differences in uplift and littoral transport. Clearly, there is a diachronic or time element involved here Boquerón and Coroso belong to different time periods of Caribbean prehistory

El Cerrillo Controversy: A Geoarchaeological Perspective

As an additional example of the model's usefulness, let us consider briefly the lithic site of El Cerrillo, in Cabo Rojo This site was not included in Chapter 4 as it is a workshop rather than a habitation site, and therefore the principle of ESM cannot be applied as precisely as to shell middens Approximately 1 km from the west coast El Cerrillo has been regarded as a preceramic workshop roughly contemporary with the Mordan Barrera complex of the Dominican Republic, and tentatively dated at 4000 B P (Ortiz 1976, Pike and Pantel 1974) This has stirred controversy, as other researchers suggest that El Cerrillo may well have been the workshop of late prehistoric ceramic cultures (Dávila 1985 41) The present model suggests Ortiz (1976), Pike and Pantel (1974) may be correct in interpreting El Cerillo a preceramic workshop, which was originally located closer to the 3000-4000 B P paleoshore

On the north coast of St. Thomas, which apparently has undergone less uplift than SW Puerto Rico in prehistory, Loveulund Quarry is located roughly 600 m (1,970 ft.) inland from the preceramic middens at Magen's Bay (Tilden 1978: 240, Fig. 1). In terms of cost-benefit, it makes perfect sense to imagine the people of Magen's Bay living by the seashore, and walking to the nearby workshop of Loveulund as needed. If this interpretation is correct, El Cerrillo is simply a much more uplifted version of Magen's Bay, and there should be preceramic middens somewhere between this workshop and the west coast. Assuming that beach ridges may be identified from aerial photographs, the "lost middens" should be found on the inland side of those ridges.

Modification of Submerged Sites: Isla Verde Case Study

Of the two submerged sites of Isla Verde and Cayo Ratones, the former has been extensively studied by the author (Vega 1981, 1982 and subsequent observations). Isla Verde is located off a coast currently undergoing severe erosion, and as such presents an interesting case study on submerged site modification.

The erosion rate of Punta el Medio has been estimated at 1.9 m/yr (Domínguez et al. 1986: 51). During a 300-day monitoring period (31 Jan 85 to 27 Nov 85), these researchers observed that erosion dominated from January to mid May, followed by accretion until late June, and then again erosion with some limited deposition from August to November.

As previously described, Isla Verde Site is located on the inshore side of a large beachrock pavement. The midden is located 160 m (525 ft.) off the seawall at the tip of Punta el Medio, at a depth of 0.2 m (.65 ft.). The

beachrock pavement flanks the midden nearly on three sides, affording protection from both surf and the prevalent west-bound longshore currents

Without question, the surficial levels of the midden have been disturbed by sediment movement This may be true of the entire site although the presence of Elenoid potsherds on the surface of the sea-bed, but not below, suggests otherwise (Vega 1981 66) Either way, it is clear that this submerged site has survived transgression at least as an assemblage Culturally-relevant information from this site can and has been extracted, very much as on a land site

In principle, site modification factors at Isla Verde include 1) surge, 2) longshore currents, 3) marine animals and 4) human activity As previously mentioned, the site is located behind a small islet, within a lunate embayment partly blocked from the open sea by offshore reefs of eolianite origin It is here, on the offshore reef, that the largest waves break A smaller, second line of breakers rolls at the edge of the beachrock pavement, over 100 m (328 ft) north of the islet, as may be seen in aerial photographs (Vega 1981 40, Fig 10) Finally, small waves <0 8 m (2 6 ft) break against the beachrock islet immediately north of the site In short, the site suffers little attack from waves

The south or shoreward end of the midden may have drifted in a general westbound direction, due to the effect of longshore currents Partial erosion of the midden is also possible. Aerial photographs (1937 onwards), together with the authors personal observations (1972 onwards), demonstrate that the channel between the site and the shore has both widened and deepened through time As an adolescent in the 1970's, during low tide, the author and various friends once managed to wade across 80%

of the distance to the islet near the site. Today, anyone under 2.4 m (7.8 ft.) in height would not be able to repeat this "feat."

Yet, the area immediately behind the midden has suffered relatively little modification other than the seasonal variation of the minuscule beach at the SE side of the islet. In some ten years of careful observation, the author has noticed no significant changes in the midden's composition or physical appearance. Apparently, both the beachrock pavement and the adjacent reefs act as a barrier to the erosive affect of ocean currents.

Recently, the passing of Hurricane Hugo offered a unique opportunity to study the site following extremely adverse conditions. While the eye of the hurricane wrecked the east coast, winds of 60 knots (mph) and up blew against the site area. On the east side of the embayment, at Isla Verde Beach, the pines and palm trees suffered such damage that the locals hardly recognized the place. It was as if an angry god had stolen the beach and replaced it with another. Where the trees should have been there was only a wasteland so barren that it revealed the full landing strip of the airport behind it. At Punta el Medio, waves tore a shorefront wall and wiped out parts of of a hotel terrace at the point. The grass at the center of the islet was literally uprooted by waves hauncing against the built-up coast. After the hurricane, the author snorkeled to the site with slate in hand. The midden was intact. In the shallowest places, the seagrass had been cut down to the roots but those roots were still there.

The impact of marine fauna on submerged land sites is little known. At Isla Verde, small gobies (*Gobidae*) and lizardfish (*Synodontidae*) partly bury themselves in sand over the site. As amazing as it may sound to non divers, the author has seen an octopus collecting pottery sherds at the site. As these ceramic fragments are lighter than most stones of similar

proportions, one possible hypothesis is that the octopus preferred the lightweight potshards as housing material. Then again, perhaps he simply liked their texture. Fortunately, this unexpected type of pothunting is restricted to surface collecting!

White sea urchins (*Echinodermata*) may be seen with very small potshards attached to their spines, apparently as part of their camouflage. Snake eels (*Ophichthidae*), the false "sea snakes" of the Caribbean, often bury themselves in sand, with heads protruding out of the sea-floor. Deeper and generally permanent burrows are dug by Caribbean garden eels (*Nystactichthys halis*), although the author has not seen them at the site. Finally, there are ribbon worms, which may be found buried in muddy sediments (Randall 1964: 25, 30, 246, Carson 1955). Overall, the impact of these relatively small animals on the midden appears to be minimal if not nearly infinitessimal. Without question, these biotic disturbances more than favorably compare with the impact on terrestrial sites of cattle, agriculture, mongooses, and land crabs, not to mention construction.

As far anthropogenic disturbances, at Isla Verde these are limited to sport divers. In more than twelve years of personal observations, the author has seen about an equal number of divers staring at a manatee rib, turtle plastron bone, or perhaps a potshard, intrigued and yet never figuring out that they are swimming over the ruins of a sunken village. As the nature of these sites is better known, looting becomes a possibility. But that is a risk that must be taken. The looting of archaeological sites is a negative force to be fought with education and policing, not hush hush. The frequent situation of "Juan's site," which only Juan has seen and dug, is detrimental to archaeology and must be avoided.

Submerged Site Prediction

Now you are shattered by the sea in the depth of the waters your wares and all your company have gone down with you All who live in the coastlines are appalled by you
The Bible Ezekiel 27: 34

The sea is everything. It covers seven tenths of the globe Its breath is pure and healthy The world so to speak, began with the sea and who knows but that it will also end in the sea! There lies supreme tranquility
Jules Verne (1974 73)

The comparative approach pursued in the previous section has opened a geoarchaeological vista that is all but invisible from the individual site level of analysis Through the concept of ESM, correlations between sea level and prehistoric settlement patterns may now be explored within a strong empirical foundation Clearly, the sea and the coast are a lot more than background scenery for Caribbean prehistoric societies Instead, they are dynamic forces in constant change

The Puerto Rico - Virgin Islands Shelf

The coast of Puerto Rico may be divided by shoreline types (Guillou and Glass 1957), by drainage basins (Morelock 1978 18), by beach systems (Morelock and Trumbull 1985 187), by form, "into five types of shoreline in six separate stretches" (Kaye 1959b 51), by geographic regions (Picó 1974 357), or by tectonic setting (Morelock 1978 5), etc For the geoarchaeologist, the usefulness of these geographic or geomorphic divisions depends on the questions being asked, as well as on the scale of the investigation (Butzer 1982 43)

From the perspective of sea levels, tectonic history is by far the most relevant approach Directly or indirectly, most of the environmental characteristics of the coastal zone are highly influenced, and in cases defined, by tectonism These characteristics include submarine and subaerial relief, as well as hydrology, soils, vegetation and aspects of climate (Picó 1974 25)

In this section we will attempt to correlate the total set of archaeological sites and their ESM values, within a general consideration of the tectonic history of Puerto Rico Essentially, this is similar to what was previously done for the SW coast, except that now the scale is larger in both diachronic and spatial terms At this level of analysis, it is beneficial to perceive a wider geographic perspective, including Puerto Rico's offshore islands of Vieques and Culebra, as well as the nearby Virgin Islands With the exception of St Croix, these small islands are an extension of the Puerto Rico shelf reaching as far east as Anegada Island (Deane 1985)

North of Puerto Rico, 3500 m (11,480 ft) of tectonic subsidence has occurred since the Miocene (25 11 Ma B.P.), along the slope break of the Puerto Rico Trench (Perfait et al 1980 152) The result has been a pelagic environment and a narrow north shelf, 2 4 km wide (Morelock and Trumbull 1985 187) As a working hypothesis, it is suggested that the tilting of the Puerto Rico Virgin Islands Shelf waned by late preceramic times This explains 1) the inland position of preceramic middens on the south coast, such as Jobos, Papayos and Coroso, 2) the near absence of preceramic sites on the north coast, and 3) the relatively similar ESM values of Ostionoid ceramic sites around the island

It is no coincidence that Maria de la Cruz, the only preceramic site so far reported for the north coast, is located near the prograded outlet of the

Loiza River. This late preceramic site has been radiocarbon dated at 1920 B.P. (Rouse and Allaire 1978: 468). Since that time, sedimentation has kept up with the gradually rising sea level, as indicated by this site as well as by numerous fossil beach ridges near the outlet of the Loiza River. These beach ridges, the most extensive on the island, increase in height and presumably decrease in age as they approach the present shoreline (Kaye 1959b: 115). Based on the position of María de la Cruz and the nearby town of Loiza Aldea (founded in the 16th century), Kaye has dated the oldest beach ridges at 3640 to 4875 B.P. Noticing the evolution from marsh to ever higher beach ridges, Kaye estimated that the oldest fossil ridges were formed when the sea level was 1.8 to 5.4 m (6 to 18 ft.) beneath the 1959 MSL (Kaye 1959b: 115).

On the south coast, the preceramic site of Cayo Cofresí is located on a small islet in a mangrove lagoon, and is currently undergoing marine transgression. This site has been radiocarbon dated at 2224-2275 B.P., and contains impeccably made groundstone tools (Veloz et al. 1975: 85, 91). As described in Chapter 4, the inland sites of Jobos, Papayos, and Coroso contain no groundstone tools, further suggesting the considerable antiquity of these sites. Nonetheless, there may also be a tectonic differential behind the ESM values of Cayo Cofresí and the three inland sites. As shown in Figure 9, a fault line cuts diagonally across the Bay of Jobos and past the shelf zone into the Caribbean Sea. This is one of three known faults that cut across the south shelf, undoubtedly introducing additional tectonic diversity within Puerto Rico's south coast.

The archaeological record of Vieques and St. Thomas indicates some tectonic uplift within the span of preceramic and possibly ceramic cultures. For instance, the preceramic midden of Caño Hondo in Vieques's south coast

is roughly 70 m (230 ft.) from shore (Figueredo 1976, Rouse 1952: 556). In Culebra's south coast, the ceramic (Ostionoid) site of Playa Cascajo is some 15 m (49 ft.) inland. On the north coast of St. Thomas, the cluster of preceramic sites at Magen's Bay is some 50 m (164 ft.) from shore (Tilden 1976: 240; Fig. 1). Also on St. Thomas north coast, the preceramic sites of Krum Bay, Grambokola Hill, and Cancel Hill are roughly 10 m (33 ft.) from shore (Gross 1976, Ramsay 1940: 158). It is interesting to notice that the ceramic middens of Hull Bay, near Magen's Bay, are closer to the intertidal zone than the latter, suggesting a prograding coast up to the ceramic age. In other words, the cultural sequence is reversed, with the older preceramic middens further inland than the ceramic ones.

In Vieques, an intensive survey prepared for the U.S. Navy (Tronolone et al. 1984b, Part II, Vol. 1: 4-17) indicates that most coastal sites are presently located over 100 m (328 ft.) from shore, further supporting the hypothesis of uplift east of Puerto Rico. This is not to say that all Vieques coastal sites are inland, as at least two ceramic sites-Isla Chiva and Paremayón 3 -are presently within the intertidal zone (Tronolone et al. 1984b Volume 3).

At this point, the land-locked archaeologist could surmise that there are no sunken prehistoric sites to be found in the Virgin Islands, as both ceramic and preceramic sites have been located inland in Vieques and St. Thomas. That, however, would be a bad case of archaeological myopia. We must complete our geoarchaeological tour of the Puerto Rico-Virgins shelf before plotting the archaeological data within a sea level framework.

Off Virgin Gorda, NE of St. Thomas, at least one prehistoric submerged site has been found by dive operator-treasure hunter Burt Kilbride yielding "darkly polished Stone Age implements" (Trupp 1986

188). As these are greenstone artifacts, most likely petaloid celts, it may be tentatively assumed that the discovery in question is either a ceramic or late preceramic midden. Further north, near the NE tip of the Puerto Rico-Virgin Islands Shelf, lies Anegada Island. Rising a bare 8.5 m (28 ft.) above sea level, Anegada is so low that at times it becomes almost invisible to Atlantic sailors approaching the Caribbean in rough weather. Hundreds of ships have come to a macabre end on the northern fringes of Anegada Reef. Some sailors call this island "The Low Land." And some, perhaps not realizing the wisdom of their words, call her "The Sunken Land." In Spanish, Anegada means "The Flooded Island."

Figure 17 presents a preliminary geoarchaeological plotting of tectonic movements for Puerto Rico and the Virgin Islands. The map is based on the ESM values of the archaeological sites described above, as well as on some geomorphological considerations. The prelimary nature of the map must be stressed, as it is intended primarily as a heuristic tool to illustrate the regional, supra island application of ESM.

The tectonic tilt of the Puerto Rico-Virgin Islands Shelf is clearly reflected in the archaeological record. By comparing the age, location and ESM values of archaeological sites, we can define the tectonic and eustatic parameters necessary for any realistic reconstruction of the area's sea level history.

Without exception, the preceramic sites found in Puerto Rico, Vieques and St. Thomas are relatively recent, all of them dated at or under 3,000 B.P. (Rouse and Allaire 1978: 468, Table 13.6). For older sites, we can only assume negative evidence. In Puerto Rico, early preceramic sites comparable to Hispaniola's Merdán, Casimira and Cebaret have not been found. As previously stated, parts of Hispaniola's north coast have been

uplifted well into the Pleistocene Epoch, as evidenced by raised coral reef terraces (Alexander 1985: 181). The opposite is true for the north coast of Puerto Rico, which is a geologically sunken coast. If early preceramic peoples occupied the north coast of Puerto Rico, their sites are certainly not to be found inland. Underseas sites are the only alternative. As Sherlock Holmes would put it: "When you have excluded the impossible, whatever remains, however improbable, must be the truth."

Data from historic sites and documents indicate that the sea level has risen at least 70 cm (2.3 ft.) since the early 16th century. Shoreline migration at Aguadilla's Fort San Francisco is clearly the result of seismic movements precisely dated to 1918. However, the older historic sites on the north coast indicate a minor, but clear eustatic rise in sea level. Otherwise, if the slight submergence of the north coast in historic times were entirely tectonic, we would expect to see greater variation in the ESM values of prehistoric ceramic sites throughout the island. This is not to deny tectonism in historic times, but simply that the eustatic level of the sea has risen in the last 500 years. This eustatic change is minor, but it is there.

Sunken Land Sites: A Caribbean Model

A model of Caribbean submerged land sites is presented in Figure 19. The model is self-explanatory, but a few commentaries are in order. Midden size was estimated from the dimensions of known preceramic sites, including Cana Hondo (30 X 8 m), Coroso (20 X 20 m), Cayo Cofresí (40 X 50 m), Magen's Bay (23 X 9 m), and Jobos (15 X 15 m). These last two sites occur in clusters of 6 and 5 middens respectively, suggesting that larger

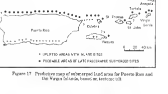


Figure 17 Predictive map of submerged land sites for Puerto Rico and the Virgin Islands, based on tectonic tilt

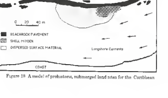


Figure 18 A model of prehistoric, submerged land sites for the Caribbean

larger middens would have resulted as a centralized deposit. For the model, a 25 X 25 m (82 X 82 ft.) midden size was assumed.

Midden shape is assumed to be the combined result of hut placement and the configuration of the coast. Sites located at beach points such as Isla Verde, Punta Mameyes and Punta Corozo will tend to be circular or oval, while sites in straight segments of coast may produce elongated middens. Of course, the shape of the midden may be transformed by post depositional processes before or after marine transgression.

Artifact and ecofact preservation at submerged land sites should not be regarded as poor, as land-bound archaeologists often assume. Stone, shell, pottery, and bone material have been found in good condition at Isla Verde. Moreover, sherds with the typical Ostionoid red slip have been retrieved both above and below the surface of the sea-bed. The only obvious evidence of artifact damage at Isla Verde consisted of a few, low-fired, courseware sherds, which crumbled after removal from the sea water, presumably through salt crystallization (Rye 1981: 10). Comparable damage has been observed on crudeware sherds excavated on land. Invariably, these are low fired ceramics.

Pollen and phytolith profiles of submerged land sites may be retrieved through coring or during excavation, as on a dry-land site (Gifford 1983: 277, Ruppé 1980a: 41). Submerged land sites may be partly sealed in anaerobic conditions, particularly in mud or clayey deposits. In these situations, virtually anything may be preserved for millenia, including wood, fibers and bone. At the submerged sites of Tybrind Vig, off the Danish island of Fynen, wooden artifacts dated to 7000 B.P. have been excavated in good condition (Andersen 1980). Such preservation is very seldom found on land sites.

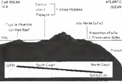


Figure 19 Schematic profile of Puerto Rico, showing tectonic component of relative sea level

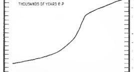


Figure 20 Preliminary geoarchaeological sea level curve for Puerto Rico's north shore, including tectonic and eustatic factors

Conclusion

> What was the shape and size and color and tone of this little expedition? We slipped into a new frame and grew to be a part of it, related in some subtle way to the reefs and beaches, related to the little animals, to the stirring waters and the warm brackish lagoons
>
> John Steinbeck (1976: 271)

> Magnificent! Magnificent!
> No one knows the final word.
> The ocean bed's aflame
> Out of the void leap wooden lambs.
> Fumon, 1302-69

The geoarchaeology of coastal change provides a new framework for Caribbean prehistory The ramifications that may be persued are vast, both above and below water Evidently, early prehistoric aborigines did not carry their shellfish for thousands of meters inland, neither did they sit around waiting for a little rain to quench their prehistoric thirst They simply adapted to new ecological conditions that were either created by themselves, such as over-exploitation, or created by strictly environmental, non social variables such as tectonism, eustatic changes in sea level, climate changes, etc

Through tectonic uplift, many streams on Puerto Rico's south coast probably dried up When that happened, the people packed their possessions and moved to a new site On the north coast, the situation was different (Figure 20) Here the sea rose a little more every year, through subsidence as well as through a rising sea level Streams may have gradually altered their course, perhaps meandering, producing marshlands and small lagoons in some areas, but never drying up

Considering that the elevation of Cerezo is 5 m (16 ft) above present sea level (Rouse 1952 379), the subduction of the north coast may be estimated at roughly 5 m since late preceramic times (3000-2500 B P) Adding a conservative estimate of 0.8 m (3 ft) of eustatic rise in sea level since then one might expect to find preceramic sites off the N coast at an average depth of 5 8 m (19 ft), as presented in Figure 20 Of course, Puerto Rico is not the perfectly rigid slab that is implied in these preliminary calculations At this point, the conceptual framework is more important than the exact measurement of tectonic tilt.

For the lowland areas of the north coast, we may estimate the ratio of sea level to shoreline migration somewhere between 1 100 to 1 1000 Stressing again the preliminary nature of these calculations, we arrive at an estimated shoreline migration of 580 to 5800 m (1,332-13,320 ft) for the north coast, since 3,000 B P Curiously, that takes us to the offshore eolianite ridges by the 5 5 m (18 ft) isobath. It is worth noting that this possible correlation was by no means forced, but rather came out as a small surprise, as the estimates given above were based strictly on the archaeological data

Suggested Strategies

Underwater archaeology need not be expensive Serious research can and has been accomplished on minimal budgets, as demonstrated by Flemming (1983) and Gifford (1983) in the Aegean Sea, by Raban (1983, 1985) off the Mediterranean coast of Israel; by Weechter (1964) off Gibraltar; by Ruppé (1980a) off West Florida by Masters (1983) off Southern California, etc

The author's own undersea excavation at Isla Verde was funded through a small donation, volunteer work, and pocket money. Excluding the Vieques-Culebra Pipeline Marine Survey, which involved a magnetometer, underwater video, a fairly large crew, etc., the dive operations behind this study were extremely simple and inexpensive. In many cases, equipment consisted of snorkeling gear, a slate and a segmented rod.

In the United States, as required by the National Historic Preservation Act of 1966, and the Outer Continental Shelf Lands Act Ammendments of 1978, leasing for offshore oil and gas exploration must be preceded by a competent, marine archaeological survey. Ironically, not one submerged land site has been located through these costly OCS surveys (Masters and Flemming 1983: 606). This is not to say that the OCS surveys are a waste of money. In addition to possible shipwreck sites, these surveys provide submarine geophysical data that will be of use to marine geoarchaeologists in the near future. In the author's case, the Vieques-Culebra Survey allowed the exploration of a 18.5 m transect (10 nautical miles) of sea bed across Vieques Sound. As previously mentioned, this resulted in the discovery of a beachrock pavement at a depth exceeding 20 m (60 ft.), 4 km away from the nearest island.

It should be possible to detect densely-packed middens through sonar, specifically with sub-bottom profilers. An experiment could be set up by reading the "signatures" of known submerged middens and then testing for other sites in high probability areas, such as Puerto Rico's north shelf, Florida's Tampa Bay (Warren 1964), etc. At present, however, the best approach to finding submerged land sites also happens to be the cheapest: snorkeling and scuba diving.

The Caribbean is one of the most popular dive destinations in the world. Virtually all the islands have diving enthusiasts. Thousands of divers on vacation from the U.S. mainland visit the region on a yearly basis. As a scuba instructor, the author is quite aware of the untapped resource that sport divers represent for archaeology. Given a certain amount of "adventure" or "mystique," divers are more than willing to volunteer their bottom time to archaeological research. In the long run, divers will either become a positive or a negative force regarding archaeology. It is essential for archaeologists to convey the importance of submerged sites to divers, and to incorporate interested divers into their work.

Archaeologists in search of submerged land sites should keep their eyes and ears open to anything related to the sea and the coast: sand extraction, offshore dredging operations, biological studies, dive shop rumors, erosion studies, shipwreck archaeology, treasure hunting, coastal and offshore construction, etc. Toponymy may also be a useful lead. Any names of points, bays, or islets related to the word "shellfish" may indicate the presence of an intertidal or partly submerged midden. In some cases, small keys may well be the remnants of densely packed middens with a higher resistance to erosion than the surrounding terrain. In sandy areas, patches of sea grasses often indicate the presence of rocks, wreck scatter or perhaps a submerged midden beneath a sand veneer. Of course, there are areas where sites may be buried under tons of sediments, in which case they may be never be found, except through the chance hit of coring operations for industrial or oceanographic purposes.

Submerged beachrock and eolianite formations are clear indicators of paleoshores. The inshore side of these formations is a good place to check for middens, particularly in the vicinity of submerged river banks. Off West

Florida, Ruppé (1980a: 36) has followed the sunken course of a river for over 8 km (4.5 nautical miles) into the Gulf of Mexico. His technique is relatively inexpensive, recording fathometer.

The importance of inland sites must not be discarded. Although the undersea is the primary place to search for the Caribbean's early preceramic sites, uplifted coasts provide a setting in which to find sites dating as early as 3000 B.P. in Puerto Rico, and possibly 4500 B.P. in Hispaniola (Ortega and Guerrero 1981, Veloz and Ortega 1976). Inland shell middens -- particularly preceramic ones -- which are away from rivers large enough for canoe navigation, should be regarded with attention to possible uplift. Of course, rivers may change their courses or dry out due to these same tectonic movements, or to new climatic regimes, but any stream large enough for canoeing will leave its imprint on the ground.

For Puerto Rico's south coast, it is fundamental to explore to what extent uplift kept up with the rising sea level. Presumably, eustasy outpaced the south coast's tectonic uplift until 7000 B.P., and perhaps up to 5000 B.P. This is presented as a working hypothesis, or rather a strategy, in order not to lose sight of the possibility of early preceramic sites submerged off the south coast. Certainly, an alternate hypothesis of early preceramic, inland sites should be kept in mind for Puerto Rico's uplifted south coast.

Site, Coast, Island, Archipelago

Based on the results of the present study, and on the preliminary interpretation of published archaeological and geomorphological data from other parts of the Caribbean, the overall tectonic trend appears to be a NE

tilt. This is in agreement with Caribbean plate motion estimates derived from the slip vectors of shallow earthquakes, which indicate an ENE plate movement of 4 cm/yr for the past 7 Ma. (Sykes et al. 1982: 10,665). As a preliminary hypothesis, it is suggested that, for the Lesser Antilles, inland sites may be found on SW coasts, with the greatest possibility of submerged sites off the NE coasts. West of Puerto Rico, the tectonic setting is far more complex, with Cuba outside of the Caribbean plate proper, and sea floor spreading along the Cayman Trough. Uplift is evident on the south coasts of Grand Cayman (Emery 1981) and Jamaica (Jones 1985), while Cuba and Hispaniola show a highly complex history of folding, faulting, depression, and uplift (Alexander 1985; Bird 1985b).

The possibility of Caribbean, submerged preceramic sites is evident, even from tectonic history alone. In spite of the outstanding number of archaeologists who have worked in the region, we still have a very superficial notion as to how the archipelago looked three, five, seven, ten, twelve, or fifteen thousand years ago. A simplistic model of eustatic change, such as the one presented in Chapter 3, can only be regarded as a first step. There is an archaeological need to reconstruct the tectonic setting of the entire archipelago.

The concept of ESM offers a new approach to the dating of archaeological sites. Intrinsically separate from radiometric dating and cultural chronology, ESM allows us to perceive spatial-temporal relationships beyond the scope of the other dating methods. In other words, the dating of a site becomes inseparable from the larger ecological framework of environmental change. Just as, for instance, ceramic typology provides a culturally-oriented dating method, ESM provides an environmentally oriented dating method.

A changing sea level may imply vast environmental transformations. Reduced coastal plains may trigger population pressure (Binford 1968), the depth, temperature, and salinity of lagoons and estuaries may increase or decrease beyond the tolerance of numerous animal species (Longhurst and Pauly 1987, Uhle 1907, Walsh 1988), coastal lowlands may be transformed into swamps, which may in turn become breeding grounds for the malaria-carrying, anopheles mosquito, changes in elevation may produce alterations in temperature and moisture content, indirectly affecting the flora and fauna (Lynch 1978: 464).

What was the impact of tectonic and eustatic movements on the topography and ecology of Caribbean islands? And what role did these environmental transformations play on prehistoric lifeways? We must answer these questions not only for the coastal regions that we see today but also for those lands that are now beneath the sea. The Caribbean possesses a vast undersea, archaeological landscape that must be explored. As jazz man Gato Barbieri once said of music: It has limits, but we do not know them.

Caribbean Maritime Hunter-Gatherers

The present study suggests that preceramic hunter gatherers ventured from the continental land masses in search of large marine fauna to hunt, and of new coastal strandflats for gathering. There is no question that the prehistoric aborigines hunted manatees and turtles. We also know that at least one stranded whale was consumed by preceramic hunters in Hispaniola (Veloz and Ortega 1976: 154). But is this an isolated historic event, or evidence of a tropical, maritime, cultural specialization process?

Wing (1978 29) suggests that prehistoric maritime lifeways require "both luck and skill to avoid the unpredictable currents wind, and waves that may destroy boats and fishing equipment " This writer would agree, if the words "luck" and "unpredictable" were replaced with "knowledge" and "largely predictable"

The sea will always possess an element of surprise The best diver may be attacked by an old or angry shark; the best captain may lose both boat and life to a hurricane or waterspout The author can attest to this through both personal experiences and shipwreck archival research But these are extraordinary events that may occur once in a lifetime

Most sea conditions are highly predictable, if people only knew what to look for (Bellwood 1979 297, Lewis 1972, Thomas 1985) The color of the sea and the clouds, the direction, temperature and strength of the wind, the movements of birds, fish, and porpoises, the patterns of sea weed on the surface of the water, all of these speak a secret language to be discovered by the careful observer If one can learn the basics of sea prediction in a few years of observation, consider how much could be learned in centuries of accumulated cultural experience, and this not simply for the beauty of it and the quest for knowledge, but for sheer survival If the secret lore of Caribbean prehistoric navigators is now unrecognized by anthropology, it is not because such lore was poor or nonexistent, but rather because the cultures that created it did not survive to tell us about it

The hypothesis of sea hunters does not preclude the hunting of land fauna such as sloths, tortoises, rodents, etc There is no cultural law that forces people to chose between the sea and the land In the Greater Antilles, a number of bands may have chosen to live in the hinterland, perhaps with little or no contact with the coast However, if such an Antillean "Paleo-

Indian" horizon ever existed it was probably short lived, for the islands big game was virtually restricted to a few species of sloths (Olsen 1978 1982) In the prehistoric Caribbean, most big game was to be found in swamps, in estuaries, and at sea If there was ever a big game hunting tradition in the Caribbean Archipelago, it was almost certainly related to the sea.

Caribbean archaeologists need to develop models specifically designed for the region's tropical, maritime environment The present study has explained the tectonic and eustatic parameters of Caribbean sea levels A methodology for reconstructing paleocoastlines has been presented. The next logical step is to search for submerged preceramic sites off the north coast of Puerto Rico, and to take a closer look at the preceramic, inland sites on the south. Sites like Jobos and Coroso should be "reopened" and dated through radiocarbon testing The islands from Vieques to Anegada are the natural extension of the present study, as is, in a wider sense, the entire archipelago By rethinking Caribbean prehistory in terms of plate tectonics and sea level, a fuller more dynamic view of tropic aboriginal lifeways will begin to emerge Within this framework, it should be possible to perceive previously unseen relationships between the prehistoric environment and the people who lived off it

Sea Level Geoarchaeology: Practical Applications

Archaeological methods have a wide range of uses that we are only beginning to appreciate and explore It is clear that archaeology can play a key role in reconstructing the sea level and tectonic history of the Caribbean and elsewhere Certainly the time scales of archaeology and geology are different, but 7000 or more years of prehistoric human occupation is an

ample margin for detecting and measuring Holocene tectonic and eustatic trends This is a potentially symbiotic relationship for oceanographers and geomorphologists may have a lot to say to archaeologists both in terms of methods and perspectives

Coastal geoarchaeology can be highly relevant to urban planners, particularly now that we debate the possible, global consequences of the Greenhouse Effect A by-product of industrialism, the Greenhouse Effect is caused by the release of carbon dioxide and other gasses into the atmosphere Like the glass enclosure of a greenhouse, these gasses retain heat therefore increasing atmospheric temperature, and possibly triggering a glacio-eustatic rise in sea level As in the reconstruction of past sea levels, geologists have not reached a consensus on the pace and potential threat of the Greenhouse Effect. This is partly due to difficulties in accurately measuring sea level changes, and in separating eustatic from tectonic factors However, there is substantial evidence that the sea is indeed rising on a global scale In Bangladesh, which is also subsiding due to isostatic depression at the mouth of the Ganges River, some researchers fear that, if the current trend in atmospheric warming continues, as much as 10% of that country's land will be lost to the sea in the next century (Eckholm 1986) Considering that Bangladesh is already overpopulated, and that a rising sea level may also impact the groundwater with saline intrusion, it is clear that we are dealing with a potential problem of enormous proportions

At the other end of the socioeconomic spectrum, a rising sea level implies the eventual destruction of coastal properties valued in billions of dollars More importantly, the rising water may trigger ecological disaster due to the increasing number of toxic waste areas in the coastal zone In

Holland, the sea must be fought in order to save the most productive farmlands in the country In places like Louisiana and Texas, a shoreline retreat implies the loss of invaluable offshore oil rights, measured exactly at three miles from shore (Kaufman and Pilkey 1979) In short, sea level and shoreline migration go far beyond the academic problems of prehistorians, geographers and geomorphologists Directly or indirectly sea level is as crucial to modern humans as it was to the first prehistoric navigators who paddled their canoes towards the grey profile of a distant island

Archaeology can and should play a role in the study of sea levels Our targets are the countless prehistoric and historic sites that dot the world's littoral zones These sites have a cultural, as well as an environmental history to tell If we don't face this challenge, another discipline will borrow our methods and do it for us To archaeologists, sea level research implies three potential benefits 1) making a contribution to the understanding of a practical, global problem, 2) tapping a new source of funding for archaeological research, and 3) working side by side with earth scientists In the end, to paraphrase John Steinbeck, it is all one thing, one planetary history, one fundamental reality The prehistoric hunter-gatherers of tropic islands, the monumental fortresses of the Spanish Main, the millionaires in their seaside villas, wondering if the state will pay for seawall repairs, the Marsh Arabs of Iraq in their artifical islands--they are chapters of the same human journey We may think of these lifeways as belonging to different paradigms, different worlds, but the sea knows better

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BIOGRAPHICAL SKETCH

Jesus Vega is a marine archaeologist, archival researcher, professional diver, and writer who has participated in numerous shipwreck projects in Florida, North Carolina, Virginia, Belize, Spain, and Puerto Rico. He has over seven years of experience in Spanish paleography, including three years in the archives of Seville, Madrid, Simancas, and Barcelona. In 1980 he directed the excavation of a submerged prehistoric hamlet off Puerto Rico's north shore. In 1984, he taught world prehistory at the University of Florida, and participated in the excavation of an inundated 10,000 year-old kill site at Central Florida's Aucilla River. In 1986, he worked as a consultant in Spanish paleography at the P. K. Yonge Library of Florida History. Back in Puerto Rico, he directed the Vieques Sound Marine Archaeological Survey in 1987, ensuring that the construction of Culebra Island's water pipeline would not destroy any historic shipwrecks in the Sound. From 1988 to 1989, he directed the search for the 1550 shipwreck of the Santa Maria de Jesus, described in Spanish documents as "the richest ship ever to have sailed to the Indies" up unto that time. After a year of preparations and four arduous months of marine work, employing sophisticated electronic instrumentation, he located the wreck in Puerto Rico's territorial waters. As a freelance writer, his credits include fiction in Miami's Vista Magazine, and four cover articles in the San Juan Star Sunday Magazine. He currently works as a bilingual copywriter at one of

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May, 1990

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